Appendix AG

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HABITAT USE AND PRODUCTIVITY OF THE NORTHERN GOSHAWK IN THE UPPER PENINSULA OF MICHIGAN

By

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HABITAT USE AND PRODUCTIVITY OF THE NORTHERN GOSHAWK IN THE UPPER PENINSULA OF MICHIGAN

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ABSTRACT

The northern goshawk (*Accipiter gentilis*) has not been well-studied in the Upper Great Lakes region. Since 1996, over 1100 km of call-playback surveys were conducted in the Upper Peninsula of Michigan (UP-MI) to estimate the occurrence of nesting goshawks. No new territories were found using this method. Thirty six active goshawk nests were found by visiting historic territories, and through reports from foresters and wildlife biologists. During 1998-99 we captured 12 adult goshawks (11 females and 1 male) in 11 active breeding areas using mist nets and a mechanical owl. Radio-transmitters were placed on each adult. Using telemetry location, components of goshawk breeding and nonbreeding habitat were identified from analysis of habitat use versus availability. Mean breeding season home range for 3 adult females was 829 ha (Adaptive Kernal Analysis) and 513 ha (Minimum Convex Polygon Analysis) and mean nonbreeding season home range for two adult female and one adult male was 7,653 ha (Adaptive Kernal analysis) and 4,203 ha (Minimum Convex Polygon analysis). Both pooled and individual goshawks selected hardwood and hardwood/conifer mix cover types more consistently than any other cover type for both breeding and nonbreeding season analysis. During 1996-99, mammalian predation was documented in 10 of 22 (45%) active breeding areas resulting in mortality of eight fledglings and one adult female goshawk. Productivity of goshawks during 1996-99 was 1.14 fledged young per active nest. In addition to habitat availability, the effect of mammalian predation on reproduction should be included among factors that may be causing negative impacts on the northern goshawk in the Upper Peninsula.

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GENERAL INTRODUCTION

breeding range that includes most of North America, Europe and Central Asia (Johnsgard, 1990). The breeding range of the northern goshawk in North America extends from western and northern portions of central Alaska, across most of south-central Canada, in higher elevations of the western United States including the Rocky Mountain Range, and through northern Minnesota, Wisconsin, Michigan and into many New England states. The range follows roughly the continental distribution of trembling aspen (*Populus tremuloides*).

The goshawk is a year-around resident of the Upper Peninsula (UP-MI) and northern Lower Peninsula (LP-MI) of Michigan. Postupalsky (1991) noted, between 1970 and 1990, the presence of goshawk nests in 11 UP-MI and 21 LP-MI counties. Although there are confirmed nest locations, little is known regarding the ecology of this species in the state of Michigan or the upper Midwest. Early accounts of the northern goshawk in Michigan were often brief and providing little description. Barrows (1912) noted the American goshawk entering Michigan from the north in 1906 overspreading the entire state. He also reported goshawk sightings throughout the neighborhoods of Detroit, Cadillac, and Manistee. He concluded that "it probably nests in the state regularly, but in very small numbers, and most of our records are far from satisfactory." Other studies of goshawks have been done in Wisconsin. Gromme (1935) reported several sightings of goshawks in Rusk County, Wisconsin, including known nest sites in second growth birch (*Betula* spp.) -maple (*Acer* spp.) forests. More recently, Erdman *et al.* (1998) initiated a comprehensive goshawk study involving productivity, population trend, and status of the goshawk in northeastern Wisconsin. From 1968-1992, 181 active goshawk nests were located within 77 territories, and 69 of these provided some form of reproductive data. They observed cyclic population trends between snowshoe hare (*Lepus americana*) and goshawk, as well as the rise of the fisher (*Martes pennanti*) as a goshawk predator in Wisconsin.

One of the challenges that natural resource agencies face is the ability to determine critical nesting and foraging habitat for the goshawk. Much research has been done on this aspect of goshawk ecology, primarily in the western U.S. Goshawk management guidelines have been written for the southwestern U.S. (Reynolds *et al.*, 1992). However, the guidelines and studies conducted in the southwestern U.S. cannot be accurately applied to goshawk management in other areas of the U.S. (Braun *et al.*, 1996). There are obvious differences in habitat types and elevations between the southwestern U.S. and the Upper Great Lakes region. Goshawk in the western states nest in mature Ponderosa pine (*Pinus ponderosa*), Douglas-fir (*Pseudotsuga menziesii*), trembling aspen, and lodgepole pine (*Pinus contorta*) only one of which is found in the UP-MI (Reynolds, 1982; Squires and Ruggiero, 1996).

The goals of this study were to gain a basic knowledge of, and develop a database on, the ecology of the goshawk, including productivity, home range size, and breeding and nonbreeding season habitat use in the UP-MI. Accordingly, this thesis is organized into 2 chapters and a summary. The first chapter investigates the productivity of 36 goshawk nests over a period of 4 years in the UP-MI and active nests in LP-MI, and northern Wisconsin, and potential factors affecting productivity. The second chapter analyzes home range and habitat use of five adult female and one adult male goshawk from radio telemetry data obtained during the breeding and nonbreeding seasons. A final summary chapter provides an overview of the study, and some basic conclusions that may assist biologists and other natural resource managers in their management decisions.

STUDY AREA

Upper Peninsula

The UP-MI lies in an ecological tension zone representing the transitional stage between the boreal forest (taiga) north of Lake Superior and the northern deciduous forest to the south. The climate from Lake Superior suppresses the arctic influence which favors the spruce-fir biome to the north (Verme, 1996). Vogelman *et al.* (1998) classified five primary forest types across the UP-MI as, 34% deciduous hardwood, 14% coniferous, 11% mixed conifer and deciduous, 27% wooded wetlands and 5% emergent herbaceous wetlands (the remaining 9% is nonforested land).

My study area (Figure 1) includes several specific management areas throughout the UP-MI. These include the East and West Units of the Hiawatha National Forest (E-HNF, W-HNF, respectively), Pictured Rocks National Lakeshore (PRNL), Seney National Wildlife Refuge (SNWR), Lake Superior State Forest (LSSF) in Mackinac and Luce Counties, private land in Marquette County, Champion International Corporation (CIC) and Mead Corporation (MC) lands in Dickinson and Menominee Counties, and the Iron River and Kenton Ranger Districts of the Ottawa National Forest (ONF).

The E-HNF and W-HNF are geographically separate. The W-HNF is bordered by Lake Superior on the north and Lake Michigan on the south. It extends along the Lake Michigan shoreline from Rapid River to Manistique. It extends along the Lake Superior shoreline from Shelter Bay to Shingleton. The E-HNF is bordered on the north by

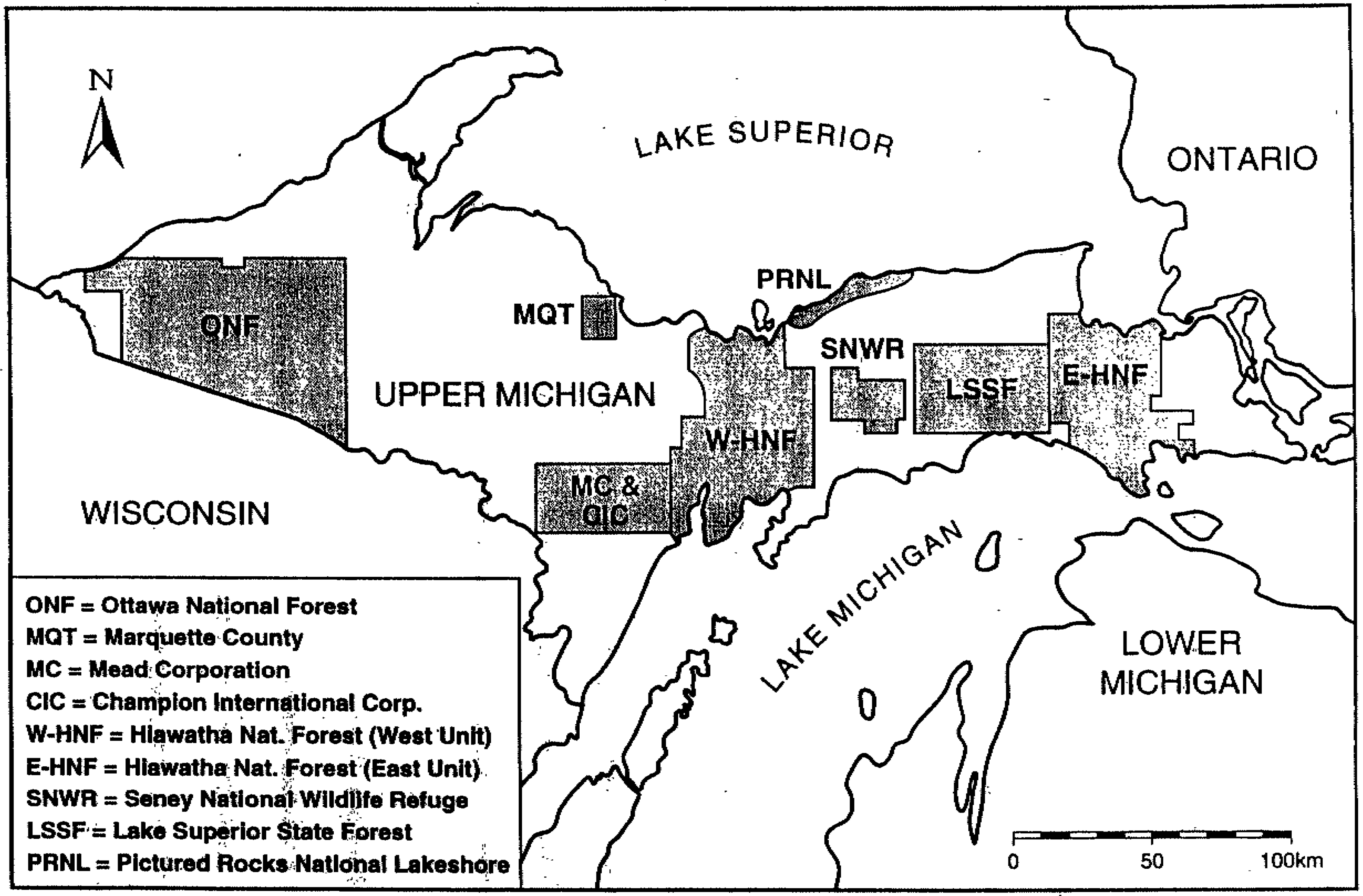

Figure 1. Location of study areas in the upper peninsula of Michigan.

Lake Superior and extends from Whitefish Bay to the mouth of the St. Mary's River. In the south, E-HNF is bordered by Lake Michigan and Lake Huron, extending from St. Martin's Bay to Brevort. The HNF consists of 361,174 hectares. Forested land comprises more than 333,481 ha. About half of the forest lands is of the deciduous type, consisting of red maple (*Acer rubrum*), sugar maple (*A. saccharum*), American beech (*Fagus grandifolia*), yellow birch (*Betula alleghaniensis*), paper birch (*B. papyrifera*), aspens (*Populus* spp.), and oak (*Quercus* spp.). The other half, respectively, is of the coniferous type including red pine (*Pinus resinosa*), white pine (*Pinus strobus*) and jack pine (*P. banksiana*), northern white cedar (*Thuja occidentalis*), white spruce (*Picea glauca*), black spruce (*P. mariana*) and balsam fir (*Abies balsamea*) (Schmidt and Lanasa, 1997).

Pictured Rocks National Lakeshore extends 40 miles along Lake Superior from Munising to Grand Marais, Michigan. Although the major vegetative type is upland hardwoods, other types, such as red and white pine, cedar, jack pine, mixed-forested wetlands, and dune communities exist in small pockets throughout the park. Land use management practices in the park include maintenance of trails and other infrastructure for recreation and tourism, but not forest management.

Seney National Wildlife Refuge is located in the Central UP-MI, just south of Seney, Michigan and west of Germfask. SNWR is a primary breeding location for a number of waterfowl species. SNWR has a total of 39,226 ha of land with nearly 60% of the wetland type. The remaining 40% is of the upland type consisting primarily of forested coniferous species such as red, white pine, jack pine, eastern hemlock (*Tsuga* *canadensis*), northern white cedar and spruce/fir. Small isolated patches of deciduous/conifer mixed-forest can be found interspersed throughout the refuge.

The ONF extends from Ironwood to Iron River, Michigan. It is bordered on the north by Lake Superior and the Keweenaw Peninsula and is bordered on the south by northern Wisconsin. The 1993 Michigan Forest Inventory revealed that the ONF contained an estimated 387,500 ha of land, of which 95% was forested. The remaining 5% were mostly wetlands, such as marsh or bogs. The main forest types contained in the ONF are maple-beech-birch (53%) and aspen (16%) with the remaining types (31%) being red pine, balsam fir, elm (*Ulmus* spp), ash (*Fraxinus pennsylvanica*), soft maples, and white cedar. As a group, hardwood forest types occupied three-fourths of the timberland (Leatherberry and Meunier, 1997).

Champion International Corporation and MC lands used for this study area include forested land in Menominee and Dickinson counties. This tract of land extends from Norway east to the Escanaba River State Forest, and is bordered by Foster City in the north and U.S. Highway 2 in the south. This portion of the study area encompasses approximately 6,000 ha, of which upland hardwoods make up nearly one-third. Other dominant forest types include, lowland conifer (~1,000 ha), aspen (~1,000 ha) and cedar (~900 ha) (pers. comm., D. Lintner).

The nests located in LSSF were in Schoolcraft, Luce and Mackinac counties. This part of the study area extends from State Highway 77 east to State Highway 123, north of State Highway 28 and is bordered by Lake Michigan in the south (pers. comm., S. MacKinnon). These nests were in stands consisting primarily of mixed hardwood conifer, upland hardwood and red pine cover types.

Regional Comparisons

Goshawk productivity in the UP-MI was compared to data from the LP-MI, northeastern Wisconsin (NE-WI) and northwestern Wisconsin (NW-WI) (Figure 2). In the LP-MI, productivity was monitored from 1996-1999 at goshawk nests on the Huron-Manistee National Forests in the following counties: Wexford, Lake, Oceana, Manistee, Crawford, Oscoda, Alpena, and Arenac (pers. comm., S. Postupalsky). Vegetation in this area is predominately continuous mixed-forest, consisting of white, red and jack pine, aspens, oaks, maples, and white birch (Bowerman *et al.*, 1993).

In NE-WI, goshawk productivity was monitored for the years 1996-1999 in the Nicolet National Forest, and from the following counties: Florence, Marinette, Oconto, Shawano, Marathon, Langlade, Lincoln, Oneda, Door, and Vilas (Erdman *et al.*, 1998). After an extensive logging and burning period prior to 1900, much of these lands have been converted to public ownership as federal, state and county forested lands. Dominant forest types include aspen, paper birch, plantation red pine and jack pine (Erdman *et al.*, 1998).

In NW-WI, goshawk productivity was monitored for years 1996-1999 on the Chequamegon National Forest and on public lands in Douglas, Bayfield, Ashland, Iron, Washburn, Sawyer, Price and Taylor counties. This part of northern Wisconsin lies predominantly within the Lake Superior clay plain, where much of the vegetation is composed of islands of red and white pine or is being converted to aspen by clear-cutting. Interior parts of the Chequamegon to the south consist of upland hardwoods, plus a high conifer/swamp component in Taylor County (pers. comm., T. Doolittle).

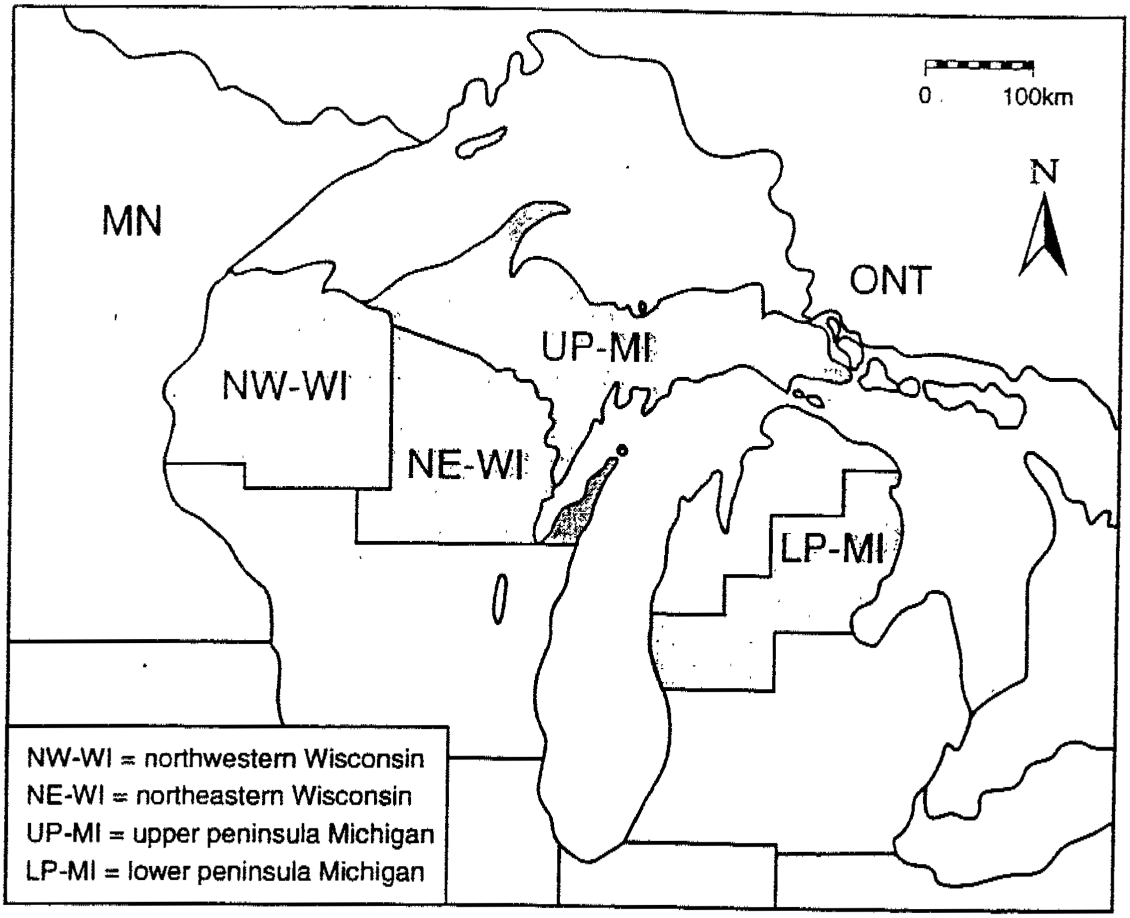

Figure 2. Locations of regional comparison study areas, upper and lower peninsulas of Michigan, and northeastern and northwestern Wisconsin.

Timber management practices have greatly influenced the vegetative structure in northwestern and northeastern Wisconsin. An exception to this is the Door County peninsula, where the tourism industry promotes management for recreation, rather than for timber. On this peninsula, many state parks consist of mature stands of maple, beech and hemlock (Erdman *et al.*, 1998).

CHAPTER 1

NORTHERN GOSHAWK PRODUCTIVITY

The northern goshawk is included on the "Sensitive Species" lists of the U.S. Forest Service (USFS) in the Pacific Southwest, Southwest, Intermountain, Rocky Mountain, and Alaska regions (Squires and Reynolds 1997). The Northern, Eastern, and the Pacific Northwest regions do not list the species. Sensitive species designation requires further biological evaluations to consider potential impacts of proposed management actions (Squires and Reynolds, 1997).

Michigan, Wisconsin and Minnesota are within the southern edge of the midwestern U.S. breeding range for the goshawk (Squires and Reynolds, 1997). The edge of the range should correspond with an area where mortality exceeds productivity (Caughley *et al.*, 1988). Thus, populations at the southern extreme of the goshawk range may have relatively low productivity, high mortality, or both.

The availability of food can explain much of the variation in productivity of raptor species. The only long-term study in this region found that goshawk populations in the Midwest appear to follow the 10-year population cycles of the snowshoe hare and ruffed grouse (*Bonasa umbellus*) (Erdman *et al.*, 1998), their main prey species. Other important factors that can potentially affect productivity of raptors include human disturbance (including habitat alteration and interruption of the nesting cycle to remove adults, eggs or young from a nest), natural predation, weather, parasites, and disease (Newton, 1979). Low food availability can also increase the effects of those other factors on productivity (Newton, 1979)

In the Upper Great Lakes region, the goshawk is poorly understood; the bulk of knowledge on this species in North America is obtained from research done in the western states, primarily Oregon, California, and Arizona (Reynolds *et al.*, 1982;

Reynolds *et al.*, 1994; Austin, 1993). At the start of this project, few data on the ecology of the goshawk (including productivity and habitat use) were known for the Upper Great Lakes region. This lack of basic knowledge illustrated the need for a comprehensive study to be conducted in this region.

In this chapter, I report data related to the method of nest location for the goshawk in the UP-MI from 1996-1999, to productivity, and to potential factors affecting productivity. These three components were analyzed for the goshawk in the UP-MI and were then compared to three other regions in the Upper Great Lakes (LP-MI, NE-WI and NW-WI).

METHODS

Nest Searches

I utilized three survey methods to locate breeding pairs of goshawks in 1998 and 1999. The first method involved using broadcast calls (tape recordings of raptor calls) on designated transects. Transects were visited between 1 May and 30 May in both 1998 and 1999. Transects were plotted through habitats likely to have breeding goshawks, such as upland hardwood, conifer and mixed conifer/hardwood stands. Lowland conifer, marsh lands and openings, while included in some transects, were of low priority in transect design. Each transect was approximately 1-3 km in length. Every 400 m, recordings of goshawk alarm call, goshawk wail call, red-shouldered hawk (*Buteo lineatus*) and a red-tailed hawk (*Buteo jamaicensis*) calls were played. Each of the four calls lasted about 5 s with a 10 s silent period between each call to allow for hawk responses (Fuller and Mosher, 1987). A full description of this method is found in Christiansen (1998). Approximately 62 km of surveys were conducted in 1998 and 1999.

The second survey method involved broadcast call surveys in historic territories. Tape-recorded calls of the three raptor species were played in breeding territories occupied previously by woodland raptors. If a raptor responded to the broadcast calls, the bird was followed and/or the area was searched until the nesting pair was located. This method was utilized in the ONF and HNF, where territory locations have been documented since the 1980's (pers. comm., K. Doran).

The third method involved responding to reports from natural resource professionals, private timber companies or the public (hereafter, referred to as reports). In this method nests were either encountered during a forest inventory without the use of broadcast call, with the use of broadcast calls following a specific survey protocol, by foresters marking timber for a timber sale, by loggers who encountered a nest during tree harvest, or by recreationists who encountered a goshawk while utilizing a trail. Nest sites were visited to confirm the location and raptor species.

Because the current study is a continuation of the earlier study, nest location data from 1996 and 1997 (Christiansen, 1998) were also included in this analysis. The three methods used in used in my study were the same methods employed in 1996 and 1997. Data from both studies have been included to provide sample sizes sufficient for statistical analysis.

UP-MI Productivity

Goshawk productivity (number of young fledged per active nest) (Postupalsky, 1974) was determined by visiting nest sites approximately once a week, and documenting the number of young and their approximate age. Active nest refers to a nest in which a goshawk pair made a breeding attempt. Mortality and disappearance of young were documented, as well as the possible cause of death. If the remains of young were found, I determined the method of feather removal, condition of remaining body parts, and distance from the nest tree. If young were missing, I searched the nest area extensively. If no evidence of predation was found, we recorded the cause of disappearance as "unknown." Young were considered successfully fledged if they were observed on trees adjacent to the nest tree, outside the immediate nest site, or were not observed (but were of appropriate age to have fledged), and no indication of predation was observed.

Banding

Between 1996 and 1999, we banded 23 young and at least one adult at 12 different sites. In those same years, no banding effort occurred at 24 nest sites. In order to test whether human activity during banding affected productivity (Newton, 1979), I compared productivity between 12 sites at which we banded and 24 sites at which we did not band either adults or young at the nest.

Regional Productivity

Annual productivity was analyzed on a regional scale by comparing mean productivity between years 1996-1999 and among areas for the UP-MI, LP-MI, NE-WI, NW-WI.

Data Analysis

Due to non-normal data distribution, nonparametric tests were utilized for statistical analysis. All statistical analysis was performed using NPAR1WAY procedure in SAS (SAS Institute Inc., 1987). Kruskal-Wallis Chi-squared Approximation was used to compare nest site location methods in the UP-MI for years 1996-99, to compare mean productivity among the four regional study areas, and to compare productivity in the UP-

MI between years 1996-99 (Ambrose and Ambrose, 1995). The Wilcoxon two-sample test was used to compare productivity between banded and unbanded sites (Daniel, 1991).

RESULTS

In years 1996 through 1999, 36 goshawk nests were located (Table 1). Of the three survey methods used, only broadcast calls in historic territories and reports resulted in the location of breeding pairs of goshawks. There were significant differences among the three methods (Kruskal-Wallis Chi-sq=9.1155, df=2, P=0.0105). Significant differences were found between broadcast calls on transects and reports, but were not found between other method comparisons.

Productivity of goshawks for 36 breeding attempts in the UP-MI was determined (Table 2). Overall productivity for the 4 year period was 1.14 young fledged per active nest. Young fledged per successful nest was 1.71 for the four years in the UP-MI. Productivity varied significantly among years (Kruskal-Wallis, Chi-sq=13.57, df=3, P=0.0036).

Productivity for one year (1998) appeared to be affected directly by predation. It was thought that our presence in the nest area and handling of the nestlings left a scent that may have led predators to the nest area (Newton, 1979, Gotmark and Ahlund, 1984). Productivity of 12 banded (mean=1.33) nest sites was not significantly different from 24 unbanded nest sites (mean=1.04) (Wilcoxon 2-sample test, Z=1.00086, P=0.3169).

Mean productivity was compared among four areas within the Upper Great Lakes region (UP-MI, LP-MI, NE-WI, NW-WI; Table 3). For the four years, there were a total of 31 active nests in the LP-MI, 70 active in NE-WI, 22 active goshawk nests in NW-WI.

Table 1. Comparison of nest location methods for the northern goshawk in the Upper Peninsula of Michigan, 1996-99.

Year	BC/TS[b]	BC/HT[a,b]	REPORT[a]
1996	0	0	8
1997	0	1	5
1998	0	0	11
1999	0	2	9
TOTAL	**0**	**3**	**33**

[a,b] = different letters indicate a significant difference ($p<0.05$) between groups using Kruskal-Wallis multiple range test (SAS Institute Inc., 1991).

BC/TS=Broadcast call on transect
BC/HT=Broadcast call in historic territory

Table 2. Northern goshawk reproductive outcome in Upper Peninsula of Michigan, 1996-1999.

Year	No. Nests	Fledged Young Median (Range)	Productivity Young/Active Nest
1996	7	0 (0-1)	0.29[c]
1997	6	2 (1-3)	2.17[a]
1998	11	1 (0-2)	0.82[b,c]
1999	12	1.5 (0-3)	1.42[a,b]

[a,b,c] = different letters indicate a significant difference ($p<0.05$) between groups using Kruskal-Wallis multiple range test (SAS Institute Inc., 1991).

Table 3. Reproductive outcomes of northern goshawks nesting in the Northern Lower and Upper Peninsula of Michigan, and Northeastern and Northwestern Wisconsin, 1996-1999.

Area/Year	Active Nests	Fledged Young	Mammalian Predation Nests	Young per Active Nest	Successful Nests (%)
Lower Peninsula Michigan	**31**	**50**	**0 (0%)**	**1.61**	**22 (71%)**
1996	10	10	0	1.00	22%
1997	8	15	0	1.88	32%
1998	7	12	0	1.71	23%
1999	6	13	0	2.17	23%
Upper Peninsula Michigan	**36**	**41**	**9 (25%)**	**1.14**	**24 (67%)**
1996	7	2	1	0.29	8%
1997	6	13	0	2.17	25%
1998	11	9	6	0.81	25%
1999	12	17	2	1.41	42%
North-Eastern Wisconsin	**70**	**100**	**20 (29%)**	**1.43**	**48 (69%)**
1996	21	33	4	1.57	31%
1997	15	23	2	1.53	27%
1998	19	26	7	1.37	25%
1999	15	18	7	1.20	17%
North-Western Wisconsin	**22**	**29**	**4 (18%)**	**1.36**	**11 (50%)**
1996	7	13	1	1.86	36%
1997	8	8	1	1.00	36%
1998	4	1	2	0.25	9%
1999	3	7	0	2.33	18%

Mean productivity from 1996-1999 ranged from a low of 1.14 (UP-MI) to a high of 1.61 (LP-MI) fledged young per active nest. There were no significant differences in mean productivity among areas and between years (Kruskal-Wallis Chi-sq=1.4, df=3, P=0.703), or for nest success rates (Kruskal-Wallis Chi-sq=2.8471, df=3, P=0.4158) among areas.

DISCUSSION

Locating nest sites of woodland raptors can be very time consuming because of low population densities and goshawks' secretive behavior and restricted visibility in forests (Kennedy and Stahlecker, 1993). Of the 3 survey methods utilized to locate breeding pairs of goshawks, reports from natural resource professionals, private timber companies and the public were the most effective in successfully locating goshawks. Reports include locating nests by surveying proposed project areas (management areas), forest inventory, reports from foresters marking trees, loggers and the public. These methods provide the opportunity for foresters, wildlife technicians and others to be in the forest more often and often in remote areas. Because of a concern for future listing, many resource agencies and timber companies have initiated surveys for goshawks on their lands (Reynolds *et al.*, 1994). Many National Forests and private timber companies have a raptor survey protocol, to inventory proposed project areas or potential future timber management sites. This protocol is similar to or a modification of the methods I used to locate active goshawk nests using broadcast calls.

Broadcast calls and visits to historic territories have been effective in locating pairs of goshawks in other parts of the country. Searching historic territories can be one of the quickest and easiest ways to find nests, considering the strong nest site fidelity of the goshawk (Bosakowski, 1999). Doyle and Smith (1994) located 6 active goshawk nests by reading signs left on the ground (prey remains, egg shells), 7 nests by broadcast calling and 5 by checking historic territories in southwest Canada. Reynolds *et al.* (1994) located 76% of their active goshawk nests during visits to historic territories and 13% during broadcast surveys in Arizona.

Effectiveness of broadcast calling to locate breeding goshawks may be highly dependent on the stage of the breeding cycle and the time of day the calls are performed. This may be one of the factors influencing my success with this method for both transects and historic territories. To locate successfully breeding goshawks, searching for nests during the nestling stage and early in the fledgling-dependency period may be the most advantageous time, as opposed to the incubation period when the female rarely leaves the nest and eggs (Kennedy and Stahlecker, 1993; Fuller and Mosher, 1981; Speiser and Bosakowski, 1991). However, surveying for nests at this time may cause researchers to miss early season breeding failures, therefore potentially overestimating productivity. Consequently, broadcast calling should be used in conjunction with other methods for locating nests, such as checking historic territories early in the breeding cycle.

In this study, we observed an increase in nest defense of the female as the breeding season progressed from egg laying to fledging, and a decrease as the young moved from the nest to adjacent trees. If calls were played too early in the breeding season, for instance when adult females were incubating eggs, they would often not respond to the broadcast raptor calls. Kimmel and Yahner (1990) and Joy *et al.* (1994) observed that goshawk's response to broadcast calls were more frequent during the nestling period rather than the fledgling period. Most of our nest searches occurred between 1 May and 1 June, when the adults were either incubating or the eggs were likely hatched, but very young. The birds may not have responded as aggressively during these times, resulting in fewer breeding pairs found.

Survey efforts in PRNL resulted in no active goshawk nests between 1996 and 1999. Pictured Rocks is a part of the National Park System, U.S. Department of Interior and does not employ foresters or timber markers. Therefore, much of PRNL is not visited on a regular basis. Transects walked in the park in 1998 and 1999 (total ~62 km) were widely dispersed, and covered a substantial area of upland hardwood and conifer stands. Still, much of the park went unchecked.

Pictured Rocks is not managed for timber and the upland hardwood forested condition is relatively continuous, rather than containing a diversity of stand types, resulting in less forest edge. The 23 nesting pairs in 1998 and 1999 in other parts of the UP-MI, nested in a diversity of stands, possibly to provide for different areas to hunt and an increased number of prey species. During the same time period of this study, the Huron Mountain Club (HMC) was surveyed for breeding birds (pers. comm., M. Keilb). The Huron Mountain Club is located approximately 23 km north of Marquette, and lies just west of Big Bay and east of L'Anse. This area is restricted from any public use, contains some of the largest white pine and hemlock stands in Michigan, and is also characterized by continuous forest stand types with less forest edge. Upon searching the approximately 8,100 ha area, Keilb did not encounter a single active goshawk nest. This could be due in part to a lack of accuracy in search design and effort, (i.e. they were nesting but were unobserved), or they simply were not nesting there. Perhaps, goshawks depend on disturbed forests for successful breeding. Landscape alterations by man may favor raptors by improving food supply and hunting opportunities (Kenward and Widen, 1989).

Goshawk productivity in the UP-MI varied greatly among the four years monitored (Table 2). In 1996, productivity (0.29 young/active nest) was statistically lower than in 1997 (2.17 young fledged/active nest) and 1999 (1.42 young fledged/active nest), probably due to the severity of the previous winter. Lake Superior retained ice flows into June, and temperatures that winter often reached record lows (National Weather Service website, http://www.crh.noaa.gov). This may have caused egg failure during early breeding attempts. Additionally, weather may have indirectly caused breeding failure by influencing prey availability (Newton, 1979). Due to the cold spring, prey species may not have emerged or migrated back to the area. The percentage of unsuccessful nests of goshawks has been correlated with precipitation during spring in the Mediterranean, with cold and wet spring months resulting in a late breeding season and fewer successful nests (Penteriani, 1997). Nest failures in this area were attributed to reduced hunting success (Penteriani, 1997).

The sample of goshawks used for this study may not be representative for production estimates due to the timing of nest searches. Because of time and weather conflicts, nest searching did not begin in most years until mid-breeding season, when the young were already hatched. As a result, it is possible that only the successful nests were found. Additionally, many nesting goshawks may have not been detected due to the lack of response when adults are on eggs. Therefore, productivity in this study should be regarded as an overestimate of actual productivity. Although not estimated in this study, survival rates for various age groups and abundance would be useful for establishing minimum reproductive output and to assess the stability of populations (Kennedy, 1997). Important aspects of locating active nests and monitoring reproductive success must include locating early season breeding failures, and determining the number of eggs laid in the initial clutch.

Predation occurred in some form at 9 (25%) of the 36 active nests between 1996-1999 in the UP-MI (Table 3). In 1996, two young were confirmed dead due to mammalian predation. No recorded predation occurred in 1997. In 1998, five dead young were classified as fisher attacks due to the nature of the carcass left behind, or other indicators including claw marks on the nest trees. Three other young were found dead, but were too decomposed to determine the cause of mortality. In 1999, one fledged young and one adult were lost to mammalian predation. The adult female was found dead below the nest tree early in the breeding season. Unknown loss of young occurred at five (14%) of the 36 active nests.

Productivity for the four years of this study was at the lower end of the range from other areas in North America (Table 4). Several factors may have contributed to low productivity in this region. Weather related factors, such as cold (lower than average temperature) springs may have delayed reproduction, reduced prey availability, or both. A cold spring may have been a factor in low productivity in 1996 when the UP-MI had snow until the end of May. Another factor may be the role of predation and increased numbers of fisher in Michigan. One must also consider that a species on the periphery of their range may be limited by climate, a resource, or a geographical feature (Caughley *et*

Table 4. Productivity of northern goshawk populations in North America.

Location	Year	Fledglings per Active Nest (n)	Reference
Alaska	1971-1973	2.00 (33)	McGowan 1975
Arizona	1991	2.00 (36)	Reynolds *et al.* 1994
Oregon	1969-1974	1.70 (48)	Reynolds and Wight 1978
New York/New Jersey	1977-1990	1.40 (36)	Speiser 1992
California	1987-1990	1.39 (23)	Austin 1993
Michigan (UP)	1996-1999	1.14 (36)	This Study
New Mexico	1984-1988	0.94 (16)	Kennedy 1989

al., 1988). The goshawk in the Upper Great Lakes region is on the edge of its breeding range, and likely is nesting at lower densities than at the core of its range.

Mean goshawk productivity did not differ among the four research areas and between years. The mean number of young fledged per active nest (1.39) from the UP-MI, LP-MI, NE-WI, and NW-WI in 1996-99 was within the range of productivity values (0.94 young fledged/active nest for New Mexico to 2.0 young fledged/active nest in Alaska and Arizona) in other parts of the country (Table 4) (Squires and Reynolds, 1997). Despite no significant differences in productivity, predation of young is worth mentioning. Mammalian predation caused the mortality of 25% of the young in the UP-MI, 29% of the young in NE-WI, 18% of the young hatched in NW-WI and no loss in the LP-MI for 1996-1999.

Fisher were suspected predators in most occurrences in 1998. Fisher were reintroduced in Michigan's ONF in the 1960's. Since then they have moved into nearly all the northwestern and central counties in the UP-MI, including Marquette, Alger, Delta, and Dickinson counties (Cooley *et al.*, 1997). Northeastern Wisconsin has fisher and uses mammalian exclusion devises on nest trees (Erdman *et al.*, 1998). The UP-MI has fisher, and has not yet implemented the use of mammalian exclusion devises to deter predators. Since exclusions have not been implemented in the UP-MI, we may be observing higher occurrences of fisher attacks in the UP-MI as opposed to NE-WI and NW-WI. Fisher and goshawk populations in Canada have maintained stable levels, and historically lived this way in Wisconsin and Michigan (Erdman *et al.*, 1998). One attributable factor to this decrease in the degree of co-existence may be the loss of extensive, continuous, mixed hardwood and conifer forests that occurred prior to

European settlement. Perhaps this forested situation provided more concealed nesting sites that protected the nests from predators, such as the fisher (Erdman *et al.*, 1998). The relationship between forest condition and adaptation of fisher is beyond the scope of this paper, but should be evaluated to fully determine the extent of fisher abundance in the Upper Great Lakes region.

Erdman *et al.* (1998) observed annual productivity and nest success in NE-WI from 1971 to 1992 and estimated that 1.7 young fledged per nesting pair was required for maintenance of a stable goshawk population. No region investigated in this study reached this level for the period from 1996-1999. Productivity levels below 1.7 young fledged per active nest could reflect impaired reproduction for the goshawk in the Upper Great Lakes Region. Alternatively, the goshawk is on the southern edge of its breeding range in the Upper Great Lakes region and it is possible the birds are reproducing at an acceptable rate. Long-term data need to be collected and, perhaps, site-specific population models should be developed before any conclusions can be appropriately drawn.

If goshawks are experiencing impaired reproduction in the Upper Great Lakes, forest management practices should be investigated as well as effects of predation as potential population influences. Effects of timber management on my study area in the UP-MI was beyond the scope of my research; however, it has been documented by other researchers. In NW-WI, a dramatic decline in suitable nesting habitat for goshawks has been observed. This decline has been attributed to forest management practices (pers. comm., T. Doolittle). From 1979 to present, an initial population of 24 active nests declined to eight. The remaining nest sites (33%) were logged. Of the 8 active nests, only 6 appear to be capable of supporting nesting goshawks, and all 6 have shown evidence of fisher activity (pers. comm., T. Doolittle).

It is not known whether productivity of the goshawks in the Upper Great Lakes region is at sustainable levels. Important factors that should be studied include the effects of weather, predation and forest management practices. Maintaining stable populations on the periphery of the range may be unlikely if resources are limited and predation is a significant factor.

CHAPTER 2

NORTHERN GOSHAWK HOME RANGE AND HABITAT USE

INTRODUCTION

Raptors are considered to be at the top of the food chain, and management decisions concerning raptors are likely to affect sympatric species (Bednarz *et al.* 1990). Goshawk need particular characteristics of a forest for nesting and foraging requirements (Reynolds *et al.*, 1982; Squires and Ruggiero, 1996). Information on goshawk habitat use outside of the nest stand is important to land managers responsible for maintaining populations (Austin 1993). While information on nesting habitat requirements is readily available from numerous studies throughout the Upper Great Lakes region, research on habitat needs outside of the nest site is not as common (Rosenfield *et al.*, 1998; Boal *et al.*, 1999; Christiansen, 1998).

Questions concerning prey availability and habitat suitability for goshawks have prompted studies of habitat use by this species throughout much of the western U.S. and parts of Europe. Kenward and Widen (1989) contend that the availability of prey, not that of woodland habitat, is the main factor that determines an area's suitability for goshawks in Sweden. To better understand the prey needs of goshawks, habitat used to hunt for food and home range size studies during both the breeding and nonbreeding seasons should be conducted. There is limited information on forest types used by breeding and nonbreeding goshawks. Characteristics such as canopy closure and age structure have been documented as important to goshawk (Bright-Smith and Mannan, 1994; Austin, 1993). In this study, I have focused on habitat types and species composition.

My main objectives were to 1) estimate the home range size; and, 2) describe the use of habitats within a study area, within the home range and at each telemetry point for goshawks during the breeding and nonbreeding seasons. This study provides baseline information and the basic framework for further studies of habitat use by goshawks in the Upper Great Lakes region. Knowledge of habitat use for the breeding and nonbreeding seasons will allow aid in the future development of habitat management recommendations for the benefit of the goshawk.

METHODS

Capture and Banding

We captured adult goshawks using two three-pocketed mist nets and a mechanical great horned owl (*Bubo virginianus*) the first two weeks in June for both 1998 and 1999 (Figure 3). A tape recording of a great horned owl call was played during trapping. We placed two mist nets in a "V" formation near the nest tree, and set the mechanical owl between the nets. After the adult was captured, the nest tree was climbed, and the young were banded, sexed and aged. We banded the adults and young with U.S. Fish and Wildlife Service aluminum lock-on leg bands.

An AVM G3 transmitter (AVM Instrument Company, Ltd., Livermore, California) was attached to adult goshawks using a backpack configuration consisting of Teflon ribbon sewn together with biodegradable cotton thread (Figure 4). The transmitter weight (1.25 g, unencapsulated weight) was <3% of the weight of the adult bird and expected battery life was 19 mo.

Telemetry

I located radioed birds between 13 July 1998 and 30 August 1999. Goshawks were located using either a 6-element Yagi, or a 2-element "H"- style antennae, and a TR-2 receiver (Telonics, Inc., Mesa, Arizona). We attempted to locate all goshawks at least two times per week. Location times and days of the week were selected

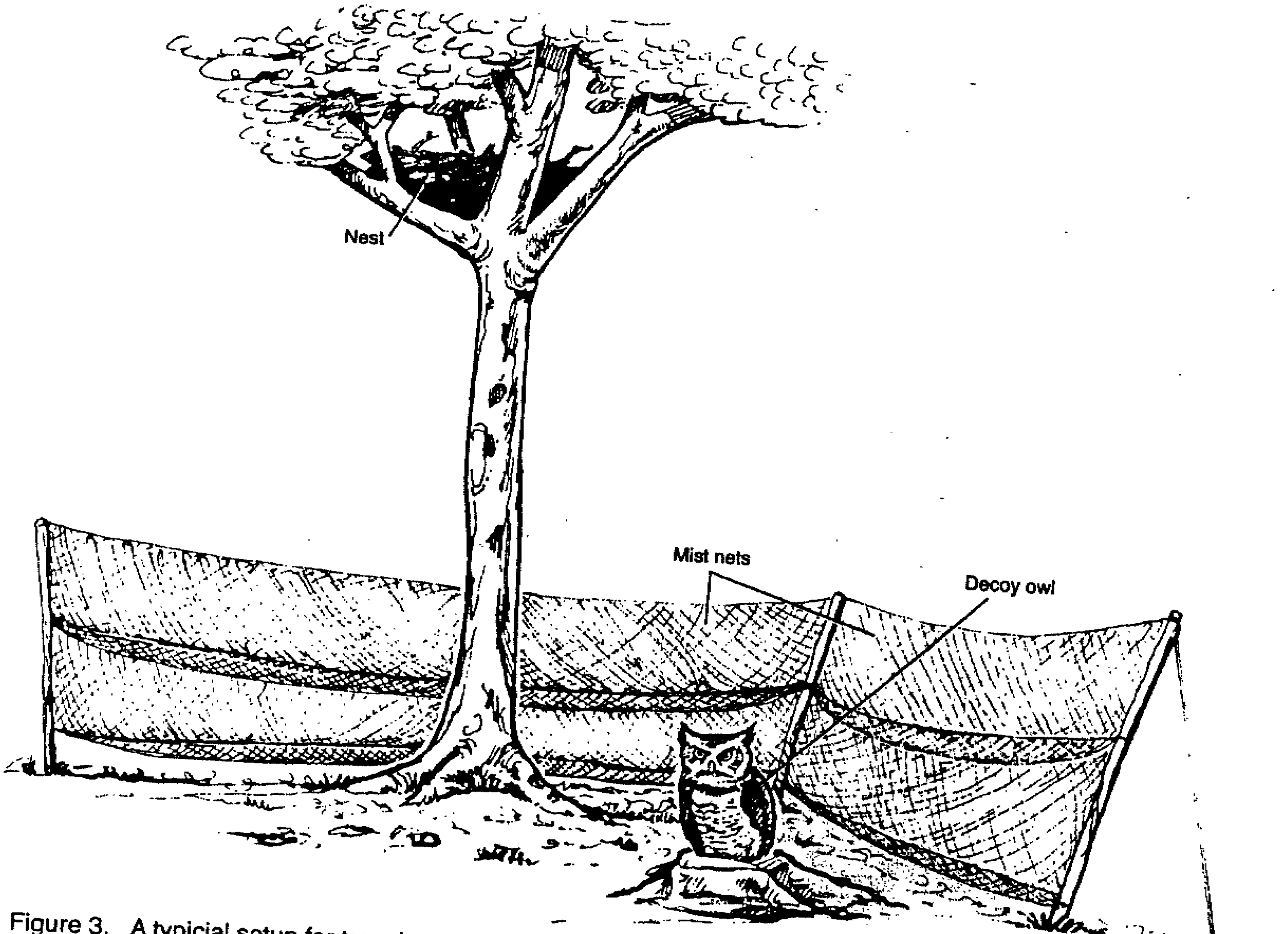

Figure 3. A typicial setup for trapping northern goshawks using mist nets and a great horned owl lure.

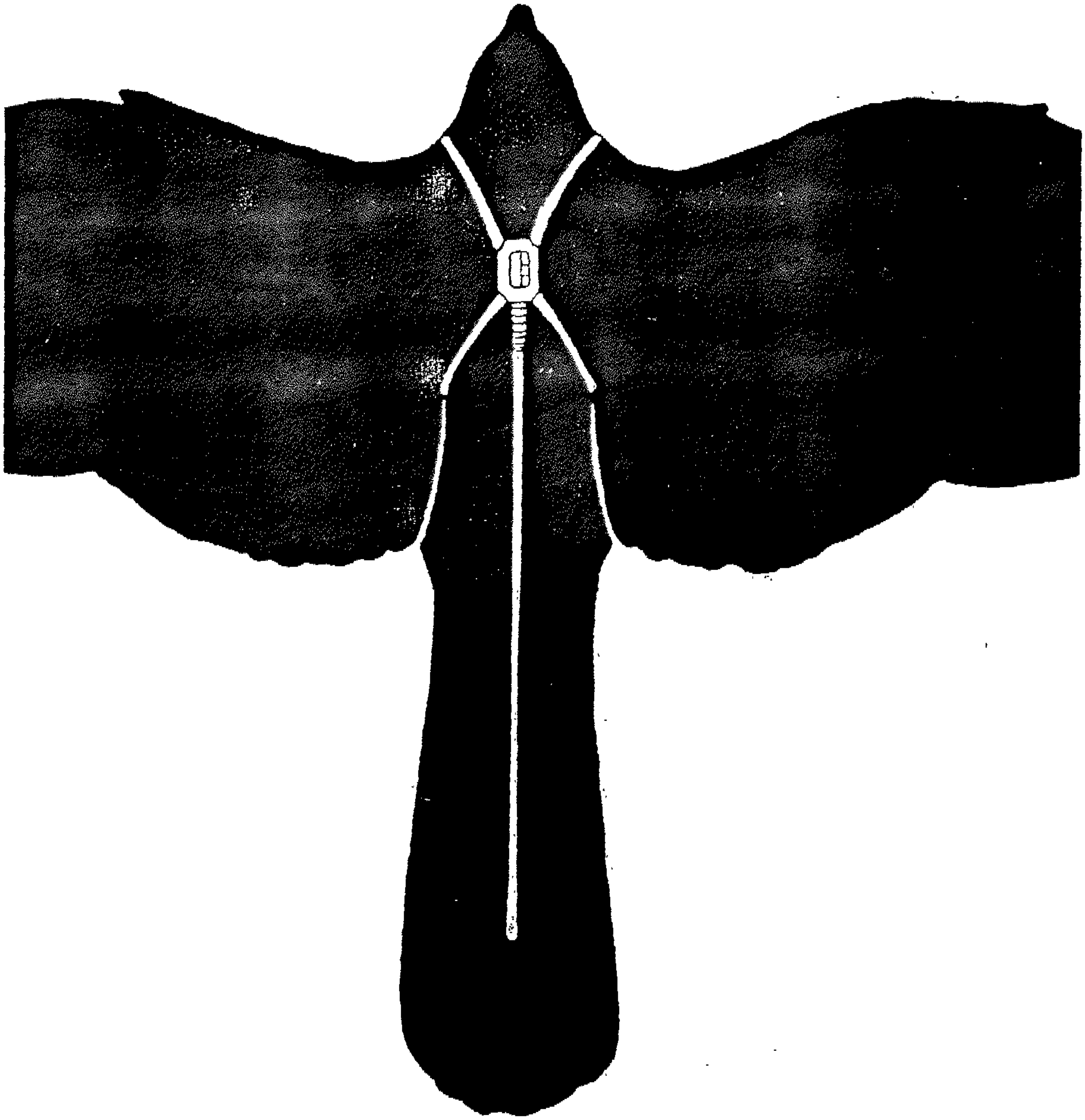

Figure 4. Configuration of a backpack style transmitter harness for use in avian telemetry

randomly to allow for independence of observations. Two locations taken at separate times were considered statistically independent if sufficient time had elapsed for the animal to move from one end of its home range to the other (White and Garrot, 1990). After plotting estimated radio-telemetry locations, Universal Transverse Mercator (UTM) coordinates and a 95% confidence ellipse using the Maximum Likelihood Estimator (MLE) were assigned for each location (Nams, 1990). Goshawk locations were accepted if the error ellipse was <16.2 ha.

Home Range and Habitat Classification

Home range and habitat use was analyzed for seven birds. Home range was calculated using the computer program CALHOME (Kie *et al.*, 1994). I used the 95% utilization distribution of both Minimum Convex Polygon (MCP) (Jennrich and Turner, 1969) and Adaptive Kernal (ADK) (Worton, 1989) methods for home range analysis. The MCP method simply connects the outer most telemetry points to form the home range. This method is a popular method for home range analysis due to the ease of calculation, however it often includes areas not used by an animal (White and Garrot, 1990). The ADK method of analysis puts more weight on core use areas (signified by large groupings of telemetry points) and less weight on outlying points or random points outside a central area of use. Breeding season (three females; 31 March-1 September) and non-breeding season (two female, 1 male; 1 September-31 March) home ranges were calculated and overlaid with eight GIS cover types for the HNF using Landsat Thematic Mapper Data (TM) (MacLean 1994). The TM satellite imagery was classified into land cover categories for the entire UP-MI with 60-m resolution. Classification accuracy was presented in the form of contingency tables that showed both errors of omission and errors of commission (MacLean 1994). The result was a complete land cover classification for the entire UP-MI with an average 90.2 percent correct (accuracy) within a 95% confidence interval.

The eight habitat categories (MacLean 1994) designated for the UP-MI were (frequently used abbreviations in parenthesis):

(1) ASPEN (ASP): Primarily aspen as the dominant species with white birch, yellow birch and related species.

(2) CEDAR (CED): Primarily white cedar.

(3) HARDWOOD (HWD): Upland hardwood forest including sugar and red maple, American elm, American beech, yellow birch, cherry, basswood, white ash, and oaks. Lower areas include, red ash, American elm, balsam poplar, and hemlock. Canopy closure was <70%.

(4) HARDWOOD/CONIFER MIX (HCMIX): Dry hardwood-conifer mix, with equal mix of hardwood and conifer (spruce and firs) in an upland environment, such species include aspen, American beech, maples and birches; also includes wet conifer/hardwood mix (including hemlock) in a low environment. Canopy closure was >70%.

(5) JACK PINE (JKP): Primarily jack pine.

(6) RED/WHITE PINE (RWP): Primarily red pine and white pine, as well as jack pine.

(7) SWAMP FIR/SWAMP CONIFER (SFSC): Primarily tamarack (*Larix laricina*), black spruce, white spruce, balsam fir and mixed conifer types (including cedar).

(8) OPEN (OPEN): Primarily non-forested areas including urban, beaches, rock outcrops, mudflats, agricultural cropland, herbaceous openland (prairies, rangelands, grasslands), shrubland, wetlands and open water.

Habitat Use

Habitat use versus availability was measured for individual birds and pooled birds for the breeding and nonbreeding season. These two components were compared with: (1) telemetry points within the home range, and (2) the home range within the study area. Habitat use versus availability differences in the ADK and MCP methods of home range analysis were also compared. Habitat use for the telemetry points and home range were compared within the study area to detect differences in cover types of the two sets of data.

Habitat availability in the study area was measured by taking a composite forest cover type based on 40 random plots (20 on the E-HNF, 20 on the W-HNF), each approximately 4000 m radius or 5000 ha area (based on the median home range size for all birds). After a grid of 12,888 squares (500 m^2=1 square) was laid over the E-HNF and W-HNF, forty random squares were chosen. I then generated a 5000 ha buffer around each square's center to give me the random plots. Pooled goshawks on the W-HNF were analyzed with W-HNF random plots and pooled goshawks on the E-HNF were analyzed with E-HNF random plots. Individual goshawks were analyzed with the random plots in the corresponding Unit (breeding season on the W-HNF, nonbreeding season on the E-HNF), with the exception of one female on the W-HNF that was tracked for the nonbreeding season. This goshawk was analyzed with W-HNF random plots.

Data Analysis

Location data were analyzed to test the hypothesis that goshawks use habitat within the study area and within individual home ranges in proportion to habitat availability in both breeding and nonbreeding seasons. All goshawks were analyzed collectively (pooled) and separately (individual). A Chi-squared goodness of fit test was used to test use versus availability for the cover types (Neu *et al.*, 1974; Livaitis *et al.*, 1994). When significant differences between use and availability were observed, Bonferoni 95% confidence intervals were calculated to determine which categories differed from expected (Byers *et al.*, 1984). The percentage of each habitat type available in the study area (E-HNF or W-HNF) and within the home range (when analyzing points only) was then compared to the confidence intervals (Neu *et al.*, 1974). Use was considered to be in equal proportion to availability if the percentage of the habitat available was within the 95% confidence interval of the habitat used. When the percentage of the habitat available was outside the 95% confidence interval, greater than random use (use greater than availability) or less than random use (use less than availability) was inferred. An alpha level of 0.05 was used for all analyses.

Habitat preference is exhibited when an animal population spends more time in certain habitats than would be expected based on the availability of each habitat type (White and Garrot, 1990). Avoidance is defined as the use of habitat types less than expected based on availability, even though the animal may not actually be avoiding the areas (White and Garrot, 1990).

The Sign Test (Daniel, 1991) was used to compare results of the ADK and MCP methods to determine significant differences between habitat use computed for each home range comparison.

RESULTS

Home Range

Transmitters were attached to seven females and one male goshawk in 1998 and four females in 1999. Breeding season location data for three females and nonbreeding season location data for two females and one male were collected from 1998-1999. Due to transmitter failure, and time and weather conflicts, the other six goshawks that were fitted with transmitters did not produce enough locations to estimate home range size and habitat use. I obtained 30 to 45 locations for each bird, per season. Home range sizes for six goshawks are summarized in Table 5. For the breeding season, mean home range size was 829 ha ADK (SD=887) and 513 ha MCP (SD=383). For the nonbreeding season home ranges, the mean was 7,653 ha ADK (SD=2,835) and 4,203 ha MCP (SD=2,448). Each home range map is shown using the 95% utilization distribution for both the ADK and MCP methods of home range analysis (Figures 5-10).

Habitat Use

Habitat use by season for 5 goshawks (pooled) are summarized in Tables 6 and 7. No significant differences were observed for the telemetry points within the ADK home range for the breeding season. Habitat use and availability comparisons for the locations of goshawk telemetry points within the MCP home range during the breeding season found that goshawks selected the hardwood cover type and avoided the aspen, cedar, hardwood/conifer mix, red/white pine and swamp fir/swamp conifer cover types

Table 5. Breeding and nonbreeding season home range sizes (hectares) for six adult Northern goshawk using both the Minimum Convex Polygon and Adaptive Kernal Methods, Hiawatha NF, Michigan, 1998-99.

Unit	Breeding Area	Sex	Season	Size (ADK)	Size (MCP)
W-HNF	Haymeadow	F	Breeding	508 ha	300 ha
W-HNF	Little Indian	F	Breeding	1,831 ha	1,051 ha
W-HNF	Manistique	F	Breeding	147 ha	188 ha
W-HNF	Hidden	F	Nonbreeding	7,346 ha	2,759 ha
E-HNF	Round Lake	F	Nonbreeding	4,245 ha	2,201 ha
E-HNF	Round Lake	M	Nonbreeding	11,269 ha	7,650 ha

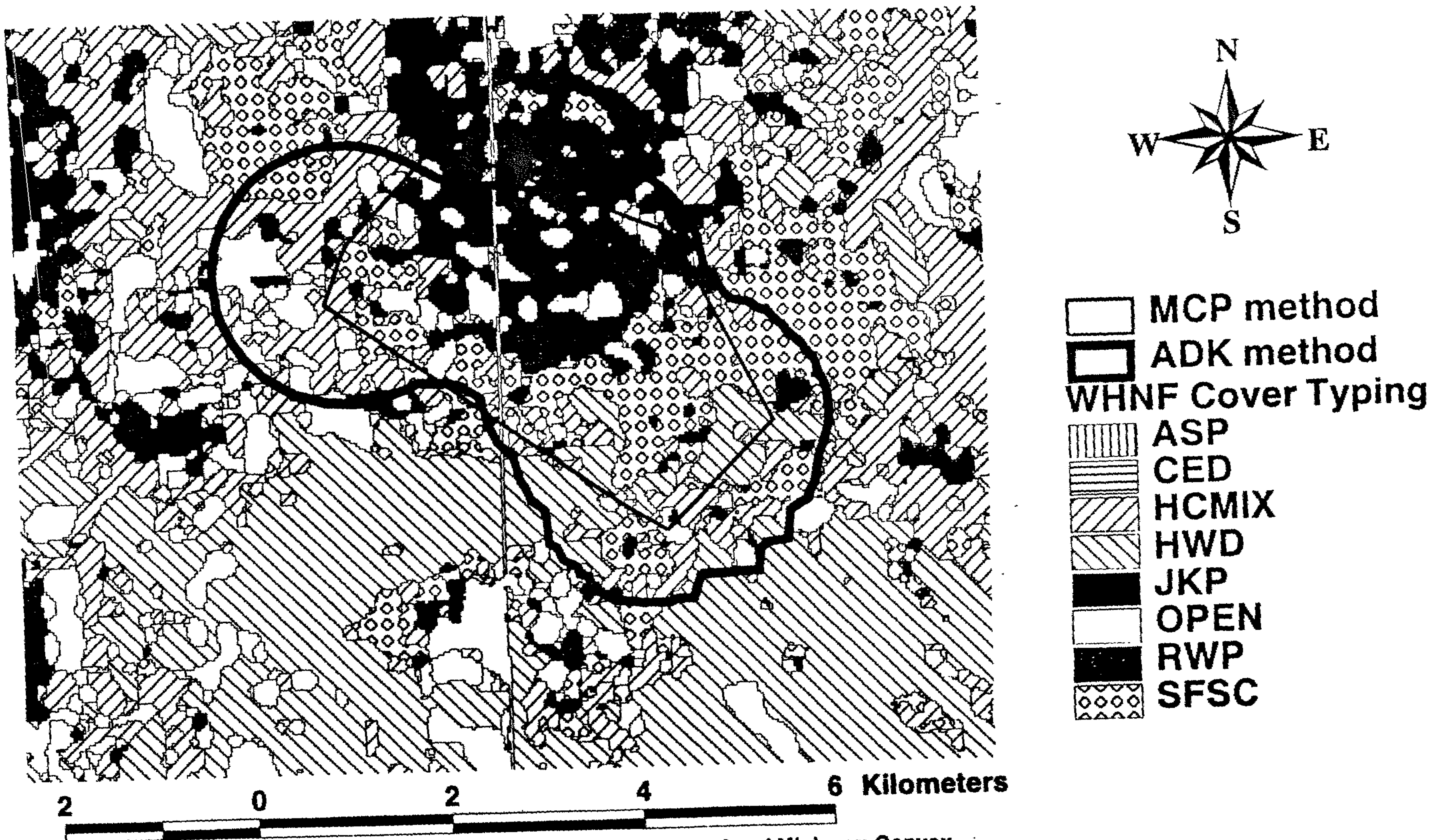

Figure 5. The 95% utilization distribution for the Adaptive Kernal and Minimum Convex Polygon methods of home range analysis for the Little Indian goshawk, breeding season, Hiawatha NF, Michigan, 1999. See text description of cover type abbreviations.

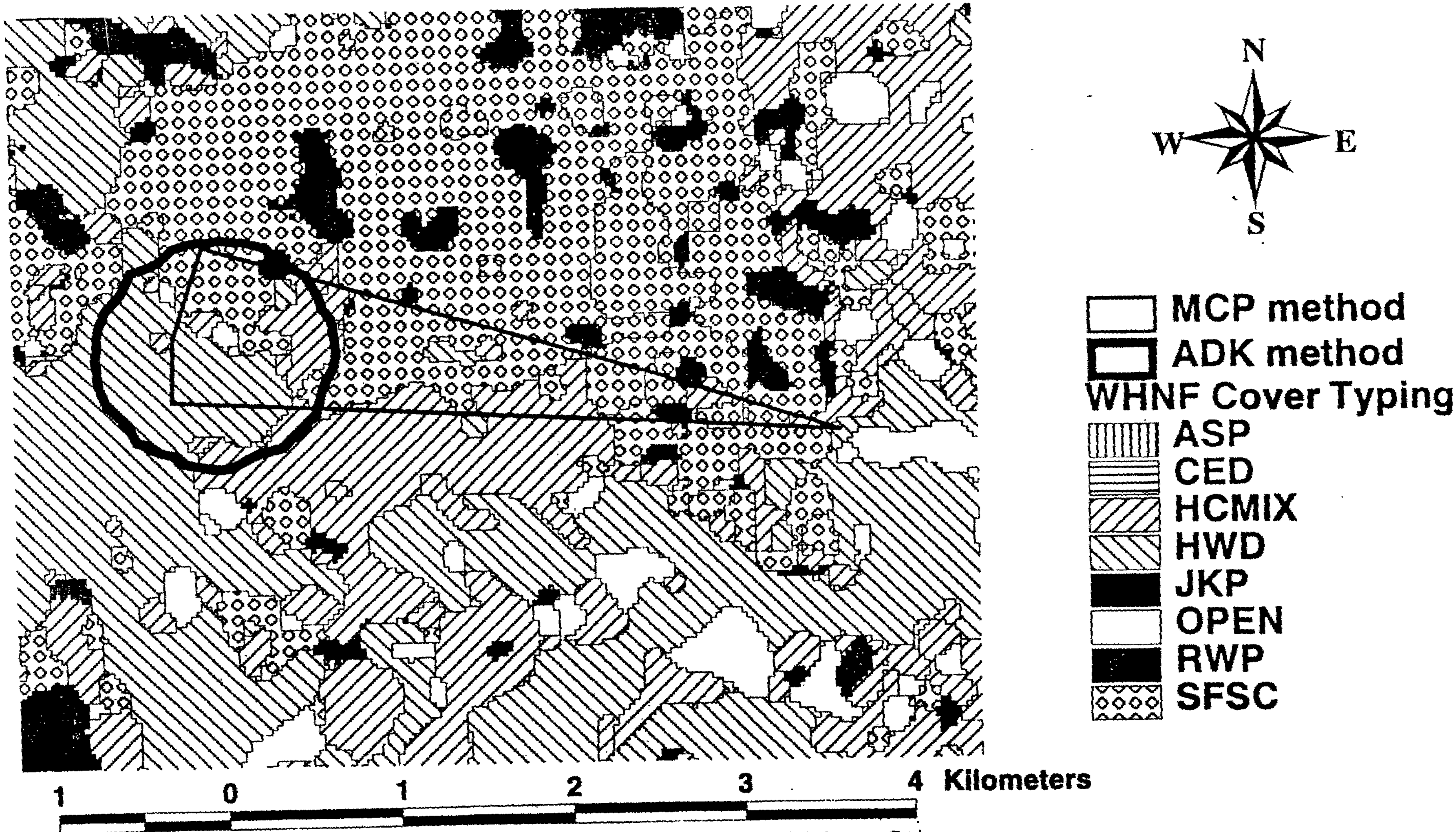

Figure 6. The 95% utilization distribution for the Adaptive Kernal and Minimum Convex Polygon methods of home range analysis for the Manistique goshawk, breeding season, Hiawatha NF, Michigan, 1999. See text description of cover type abbreviations.

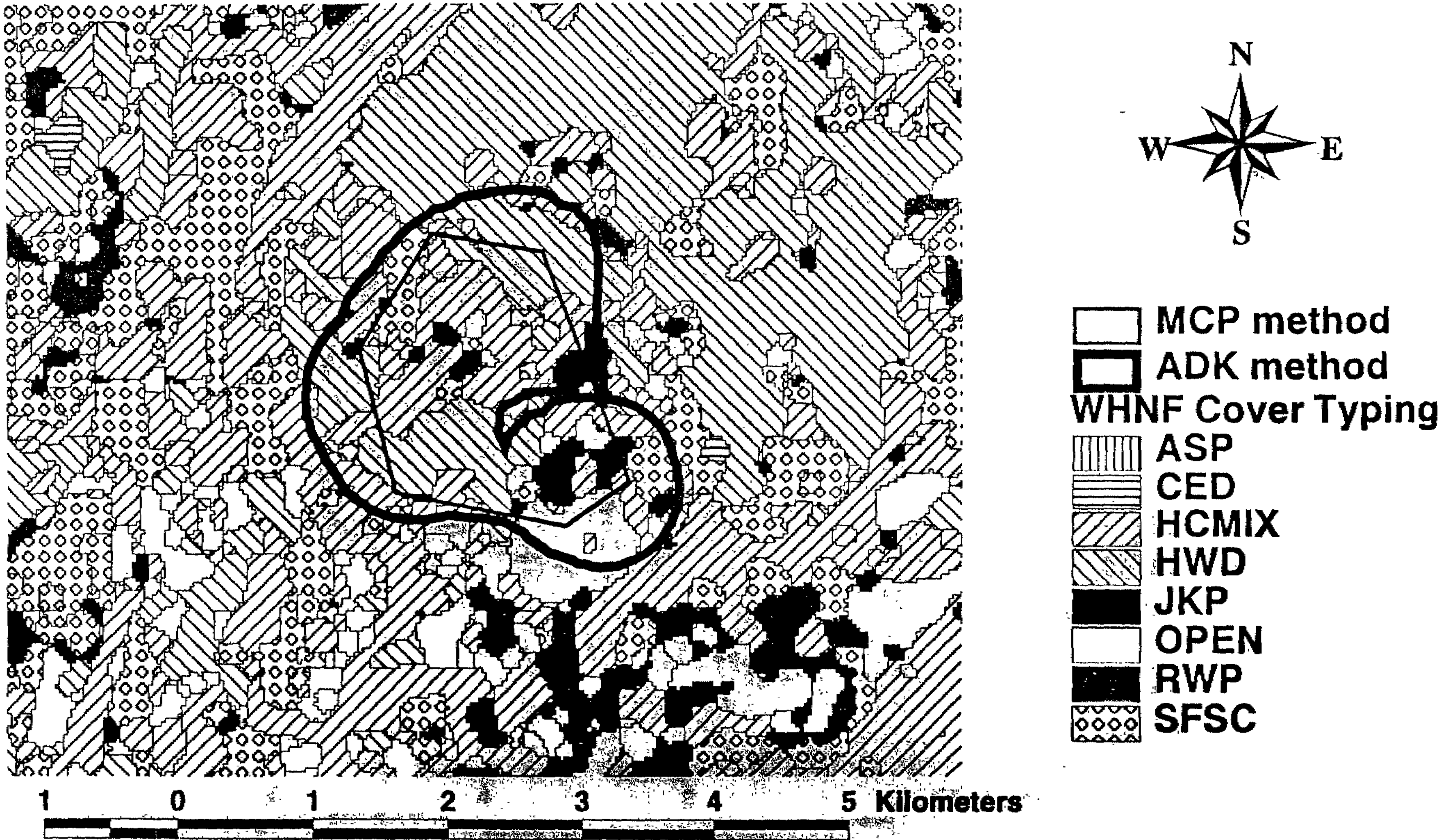

Figure 7. The 95% utilization distribution for the Adaptive Kernal and Minimum Convex Polygon methods of home range analysis for the Haymeadow goshawk, breeding season, Hiawatha NF, Michigan, 1999. See text description of cover type abbreviations.

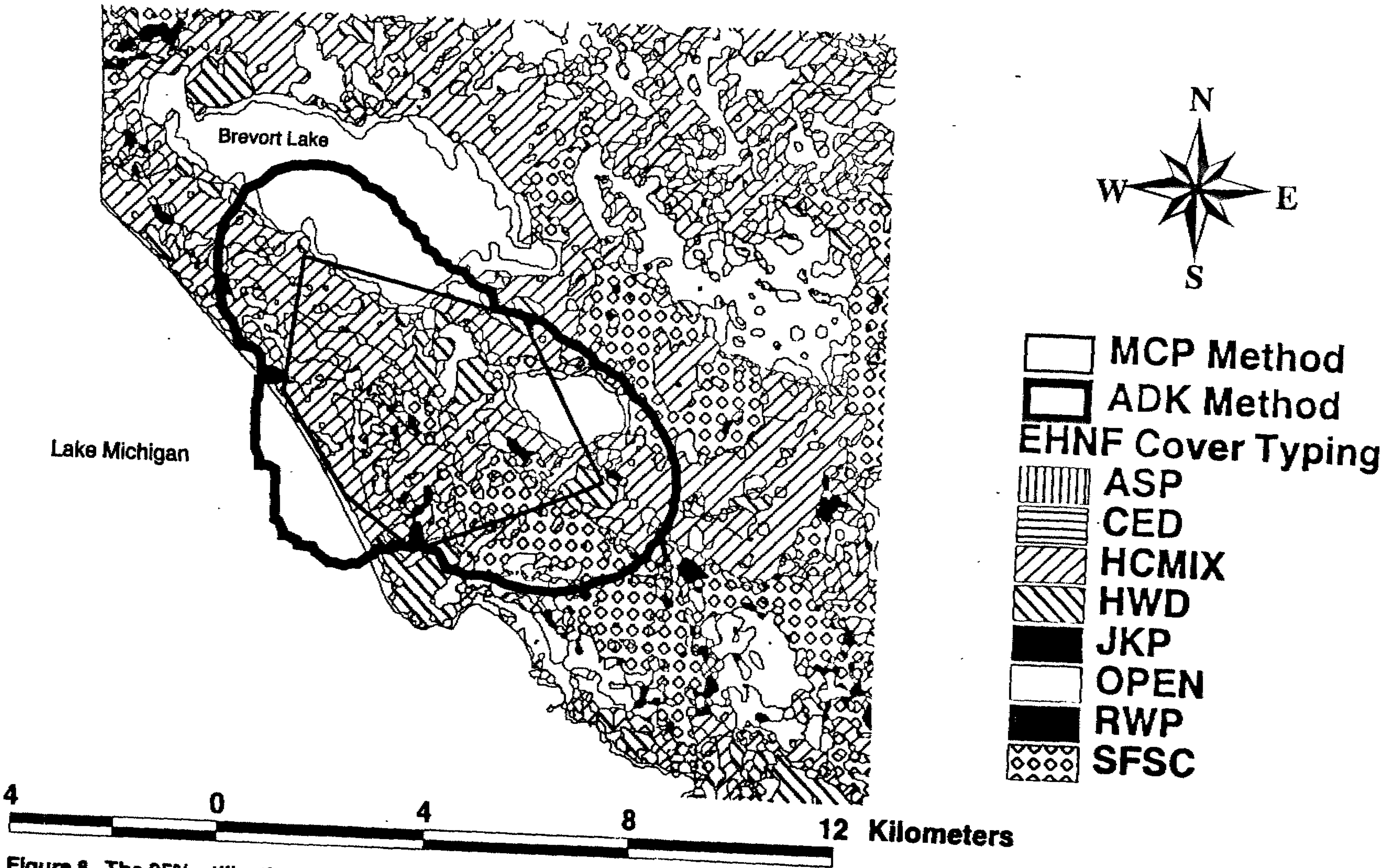

Figure 8. The 95% utilization distribution for the Adaptive Kernal and Minimum Convex Polygon methods of home range analysis for the Round Lake female goshawk, nonbreeding season, Hiawatha NF, Michigan, 1998-99. See text description of cover type abbreviations.

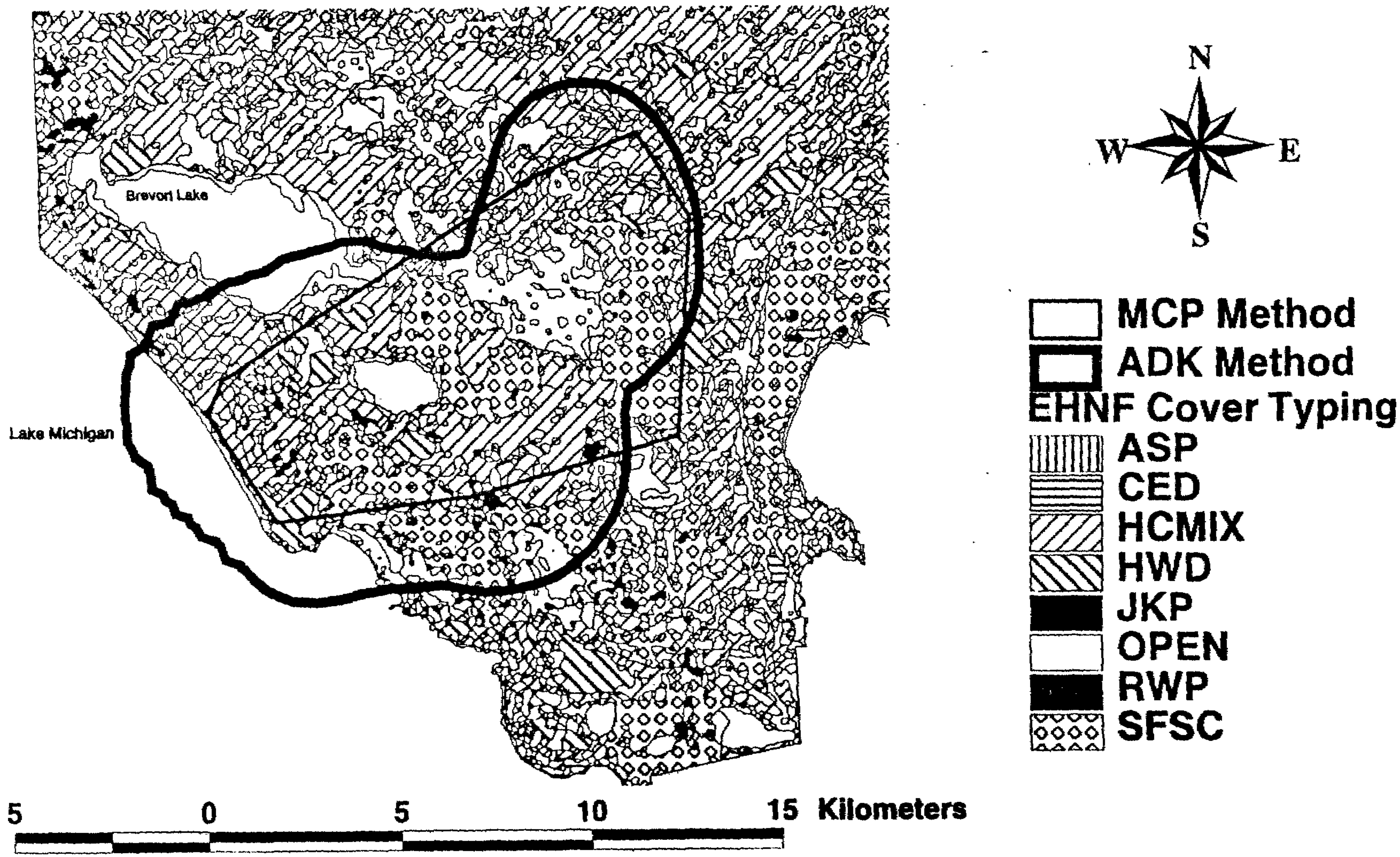

Figure 9. The 95% utilization distribution for the Adaptive Kernal and Minimum Convex Polygon methods of home range analysis for the Round Lake male goshawk, nonbreeding season, Hiawatha NF, Michigan, 1998-99. See text description of cover type abbreviations.

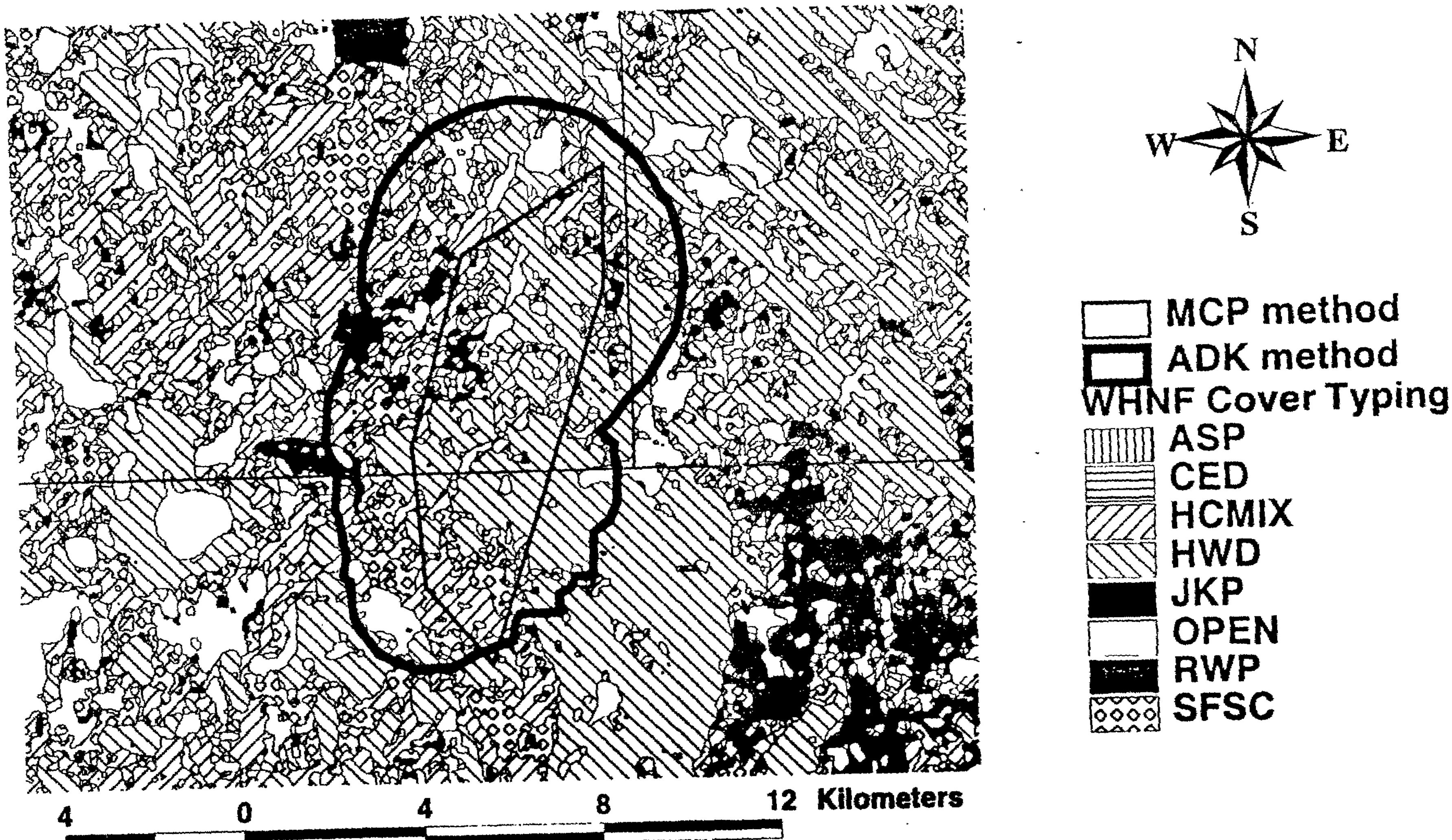

Figure 10. The 95% utilization distribution for the Adaptive Kernal and Minimum Convex Polygon methods of home range analysis for the Hidden Lake goshawk, nonbreeding season, Hiawatha NF, Michigan, 1989-99. See text description of cover type abbreviations.

=51.1, df=7, P<0.001) (Table 6). Comparisons of the locations of goshawk ry points within the home range during the nonbreeding season found that ks selected for hardwood and hardwood/conifer mix cover type, and avoided jack pine, and open cover types for both the MCP and ADK methods (Chi-.8, df=7, P<0.001; Chi-sq=37.4, df=7, P<0.001) (Table 7). The remaining cover types were used in proportion to availability.

Goshawks exhibited preference of certain habitat types for the home range within the study area during the breeding season for the pooled samples (n=3) (Table 6). No significant differences were observed for the ADK home range within the study area. Goshawks selected the hardwood/conifer mix and jack pine cover types, and avoided cedar, open and swamp fir/swamp conifer cover types for the MCP method (Chi-sq=37.6, df=7, P<0.001;).

Goshawks exhibited preference of certain habitat types for the home range within the study area during the nonbreeding season for the pooled sample (n=2) (Table 7). Goshawks selected the hardwood/conifer mix and swamp fir/swamp conifer cover types and avoided aspen, cedar, hardwood, jack pine, and red/white pine cover types for the MCP method (Chi-sq=22.8, df=7, P<0.005;). Goshawks selected the hardwood/conifer mix, open and swamp fir/swamp conifer cover types and avoided aspen, cedar, hardwood, jack pine, and red/white pine cover types for the ADK method (Chi-sq=21.5, df=7, P<0.005).

Habitat use comparisons for 6 adult individual goshawk are found in detail in Tables 8-13. Individual goshawk (n=3) exhibited both preference and avoidance of cover

Table 6. Breeding season Chi-square analysis for 3 adult female goshawks (pooled), including both home range within the study area and telemetry points within the home range, Hiawatha NF, 1999. (+)=Selection, (-)=Avoidance, (0)=Use in proportion to availability, NS=No Significant Difference.

	MCP[2] (Result)	ADK[3] (Result)	Point within MCP (Result)	Point within ADK (Result)
Chi-square value	37.6	6.3	51.1	11.0
Df	7	7	7	7
P	<0.001	<0.25	<0.001	<0.25
Cover Type[1]				
ASP	0.1 (0)	NS	2.2 (-)	NS
CED	0.5 (-)	NS	0.07 (-)	NS
HCMIX	11.1 (+)	NS	2.2 (-)	NS
HWD	0.2 (0)	NS	39.1 (+)	NS
JKP	14.9 (+)	NS	0.2 (0)	NS
OPEN	6.4 (-)	NS	0.0 (0)	NS
RWP	0.7 (0)	NS	3.1 (-)	NS
SFSC	2.3 (-)	NS	51.1 (-)	NS

[1] See text description of cover type abbreviation

[2] MCP=Minimum Convex Polygon method for home range analysis

[3] ADK=Adaptive Kernal method for home range analysis

Table 7. Nonbreeding season Chi-square analysis for 1 adult female and 1 adult male goshawks (pooled), including both home range within the study area and telemetry points within the home range, Hiawatha NF, 1998-99. (+)=Selection, (-)=Avoidance, (0)=Use in proportion to availability.

	MCP[2] (Result)	ADK[3] (Result)	Point within MCP (Result)	Point within ADK (Result)
Chi-square value	22.8	21.5	115.8	37.4
Df	7	7	7	7
P	<0.005	<0.005	<0.001	<0.001
Cover Type[1]				
ASP	1.3 (-)	1.3 (-)	93.9 (0)	0.9 (0)
CED	0.4 (-)	0.4 (-)	0.05 (-)	0.02 (-)
HCMIX	5.3 (+)	1.8 (+)	1.6 (+)	5.0 (+)
HWD	7.9 (-)	9.2 (-)	6.8 (+)	10.4 (+)
JKP	2.1 (-)	2.1 (-)	0.8 (-)	0.8 (-)
OPEN	0.1 (0)	1.9 (+)	9.1 (-)	16.5 (-)
RWP	2.0 (-)	2.0 (-)	3.0 (0)	3.4 (0)
SFSC	3.8 (+)	2.7 (+)	0.4 (0)	0.2 (0)

[1]See text description of cover type abbreviations

[2] MCP=Minimum Convex Polygon home range analysis method

[3] ADK=Adaptive Kemal home range analysis method

types for the breeding season (Tables 8, 10, 11). For the Haymeadow goshawk, no significant differences were observed for the telemetry points within either home range analysis (Table 8). Significant differences were observed for all other analysis of individuals for the breeding season. Seven of the eight cover types were selected by at least one goshawk for habitat use analysis of both telemetry points and home range. The open cover type was the only cover type not selected for by individual goshawk for the breeding season.

Preference and avoidance was observed by individual goshawks (n=3) for the nonbreeding season (Tables 9, 12, 13). For the Hidden Lake goshawk, no significant difference was observed for the ADK within the study area. All other analysis resulted in significant differences. The aspen, hardwood/conifer mix, hardwood, open, and swamp fir/swamp conifer cover types were selected by at least one goshawk for habitat use analysis of both telemetry points and home range. Jack pine was the only cover type avoided by all individuals (both telemetry points and home range habitat use analysis) for the nonbreeding season.

Cover types for each telemetry point were compared between the cover types for the two home range methods resulting in no significant differences (Chi-sq=0.5108, df=7, P>0.05). Therefore, the percent cover types within each home range method accurately reflects the cover types around the telemetry points.

DISCUSSION

I wanted to determine if home range size of goshawks in the UP-MI was consistent with that of goshawks in the western states. Breeding season ranges of the three adult female goshawks analyzed in this study, with an ADK range of

Table 8. Breeding season Chi-square analysis for the Haymeadow goshawk. including both home range within the study area and telemetry points within the home range, Hiawatha NF, 1999. (+)=Selection, (-)=Avoidance, (0)=Use in proportion to availability. NS=No Significant Difference.

	MCP[2] (Result)	ADK[3] (Result)	Point within MCP (Result)	Point within ADK (Result)
Chi-square value	36.1	15.2	9.0	7.8
Df	7	7	7	7
P	<0.001	<0.05	<0.25	<0.25
Cover Type[1]				
ASP	0.1 (0)	0.5 (0)	NS	NS
CED	0.5 (-)	0.5 (-)	NS	NS
HCMIX	11.1 (+)	6.1 (+)	NS	NS
HWD	0.2 (0)	0.0 (0)	NS	NS
JKP	14.9 (+)	3.8 (0)	NS	NS
OPEN	6.4 (-)	2.3 (-)	NS	NS
RWP	0.7 (0)	1.2 (-)	NS	NS
SFSC	2.3 (-)	0.9 (0)	NS	NS

[1] See text description of cover type abbreviations
[2] MCP=Minimum Convex Polygon method for home range analysis
[3] ADK=Adaptive Kernal method for home range analysis

Table 9. Nonbreeding season Chi-square analysis for the Hidden Lake goshawk, including the home range within the study area and telemetry points within the home range, Hiawatha NF, 1998-1999. (+)=Selection, (-)=Avoidance, (0)=Use in proportion to availability, NS=No significant difference.

	MCP[2] (Result)	ADK[3] (Result)	Point within MCP (Result)	Point within ADK (Result)
Chi-square value	16.2	5.5	35.9	47.3
Df	7	7	7	7
P	<0.025	<0.25	<0.001	<0.001
Cover Type[1]				
ASP	1.2 (-)	NS	0.3 (-)	0.3 (-)
CED	0.3 (-)	NS	0.1(-)	0.3 (-)
HCMIX	0.0 (0)	NS	6.3 (-)	6.3 (-)
HWD	8.2 (+)	NS	8.4 (+)	21.7 (+)
JKP	0.8 (-)	NS	0.4 (-)	0.2 (-)
OPEN	2.2 (-)	NS	5.9 (+)	0.3 (0)
RWP	2.9 (-)	NS	3.9 (-)	5.0 (-)
SFSC	0.6 (0)	NS	10.7 (-)	13.3 (-)

[1] See text description of cover type abbreviations

[2] MCP=Minimum Convex Polygon method for home range analysis

[3] ADK=Adaptive Kernal method for home range analysis

Table 10. Breeding season Chi-square analysis for the Little Indian goshawk, including the home range within the study area and telemetry points within the home range, Hiawatha NF, 1999. (+)=Selection, (-)=Avoidance, (0)=Use in proportion to availability.

	MCP[2] (Result)	ADK[3] (Result)	Point within MCP (Result)	Point within ADK (Result)
Chi-square value	126.3	50.0	77.9	34.9
Df	7	7	7	7
P	<0.001	<0.001	<0.001	<0.001
Cover Type[1]				
ASP	7.1 (+)	1.5 (0)	5.2 (-)	3.3 (-)
CED	0.2 (0)	0.2 (0)	0.2 (-)	0.2 (-)
HCMIX	8.3 (-)	1.6 (-)	10.6 (+)	0.3 (0)
HWD	17.6 (-)	13.7 (-)	34.8 (+)	18.7 (+)
JKP	0.0 (0)	0.8 (0)	11.4 (+)	5.2 (+)
OPEN	1.7 (-)	0.0 (0)	0.1 (0)	2.0 (-)
RWP	76.8 (+)	22.0 (+)	15.2 (-)	5.2 (-)
SFSC	14.6 (+)	10.4 (+)	0.5 (0)	0.1 (0)

[1] See text description of cover type abbreviations
[2] MCP=Minimum Convex Polygon method for home range analysis
[3] ADK=Adaptive Kernal method for home range analysis

Table 11. Breeding season Chi-square analysis for the Manistique goshawk, including home range within the study area and telemetry points within the home range, Hiawatha NF, 1999. (+)=Selection, (-)=Avoidance, (0)=Use in proportion to availability.

	MCP[2] (Result)	ADK[3] (Result)	Point within MCP (Result)	Point within ADK (Result)
Chi-square value	153.0	38.2	272.1	34.8
Df	7	7	7	7
P	<0.001	<0.001	<0.001	<0.001
Cover Type[1]				
ASP	1.7 (-)	0.6(0)	0.0 (0)	0.7 (-)
CED	0.5 (-)	0.5 (-)	0.0 (0)	0.0 (0)
HCMIX	0.1 (0)	0.5 (0)	26.7 (-)	21.4 (-)
HWD	9.7 (-)	10.6 (+)	226.2 (+)	9.6 (+)
JKP	1.5 (-)	1.5 (-)	0.0 (0)	0.0 (0)
OPEN	12.7 (-)	12.4 (-)	1.2 (-)	1.4 (-)
RWP	5.3 (-)	6.4 (-)	2.1 (-)	1.4 (-)
SFSC	121.5 (+)	5.9 (+)	15.9 (-)	0.3 (-)

[1] See text description of cover type abbreviations
[2] MCP=Minimum Convex Polygon method for home range analysis
[3] ADK=Adaptive Kemal method for home range analysis

Table 12. Nonbreeding season Chi-square analysis for the Round Lake female goshawk, including home range within the study area and telemetry points within the home range, Hiawatha NF, 1998-99. (+)=Selection, (-)=Avoidance, (0)=Use in proportion to availability.

	MCP[2] (Result)	ADK[3] (Result)	Point within MCP (Result)	Point within ADK (Result)
Chi-square value	26.2	21.3	23.6	43.5
Df	7	7	7	7
P	<0.001	<0.005	<0.005	<0.001
Cover Type[1]				
ASP	1.5 (-)	1.5 (-)	12.0 (+)	12.0 (+)
CED	0.5 (-)	0.5 (-)	0.0 (0)	0.0 (0)
HCMIX	13.4 (+)	3.4 (+)	0.3 (0)	4.9 (+)
HWD	6.6 (-)	8.6 (-)	3.7 (+)	7.8 (+)
JKP	2.0 (-)	2.3 (-)	0.9 (-)	0.7 (-)
OPEN	0.6 (0)	2.9 (+)	4.8 (-)	14.8 (-)
RWP	1.6 (-)	1.9 (-)	1.4 (0)	2.5 (0)
SFSC	0.0 (0)	0.2 (0)	0.4 (0)	0.7(0)

[1] See text description of cover type abbreviations
[2] MCP=Minimum Convex Polygon method for home range analysis
[3] ADK=Adaptive Kernal method for home range analysis

Table 13. Nonbreeding season Chi-square analysis for the Round Lake male goshawk, including home range within the study area and telemetry points within the home range, Hiawatha NF, 1998-1999. (+)=Selection, (-)=Avoidance, (0)=Use in proportion to availability.

	MCP[2] (Result)	ADK[3] (Result)	Point within MCP (Result)	Point within ADK (Result)
Chi-square value	30.0	25.3	38.8	43.7
Df	7	7	7	7
P	<0.001	<0.001	<0.001	<0.001
Cover Type[1]				
ASP	1.1 (-)	1.1 (-)	0.6 (-)	0.6 (-)
CED	0.3 (-)	0.4 (-)	0.1 (-)	0.0 (0)
HCMIX	0.9 (0)	0.7 (0)	4.6 (+)	5.2 (+)
HWD	9.3 (-)	9.9 (-)	11.6 (+)	13.7 (+)
JKP	2.1 (-)	1.8 (-)	0.8 (-)	1.0 (-)
OPEN	0.0 (0)	1.1 (0)	14.2 (-)	18.3 (-)
RWP	2.4 (-)	2.2 (-)	6.5 (0)	4.8 (0)
SFSC	13.9 (+)	8.2 (+)	0.5 (0)	0.0 (0)

[1] See text description of cover type abbreviations
[2] MCP=Minimum Convex Polygon method for home range analysis
[3] ADK=Adaptive Kernal method for home range analysis

147 ha-1831ha (mean=829 ha) and a MCP range of 188 ha-1051 ha (mean=513 ha), appear to be smaller than home range sizes of goshawks in the western states. Austin (1993) estimated a mean home range size of 3,100 ha (2,425 ha for males; 3,774 ha for females) in northwestern California. Hargis *et al.* (1994) found mean home range of 1,550 ha (5 females averaged 1,340 ha) using the 95% ADK method. In Minnesota, Boal *et al.* (1999) found an average MCP breeding season home range as approximately 2,000 ha for four adult female. The mean home range size for all radio-tagged goshawks in Minnesota was 1,090 ha (Boal *et al.*, 1999).

Breeding season home ranges are expected to be considerably smaller than nonbreeding season home ranges because adults stay closer to the young in the nest while hunting (Newton 1979). The home range sizes of two females and one male in the UP-MI were determined for the nonbreeding season of 1998-99. The range of nonbreeding season ADK and MCP home range sizes was 4245 –11,269 ha (mean=7,620 ha) with the male having the largest range (11,269 ha) and a range of 2201-7650 ha (mean=4,203 ha), respectively. As in western studies, I observed that the home range size increased as the young matured and moved out of the nest area around 31 August (Keane and Morrison, 1994; Hargis *et al.* 1994). In California, Keane and Morrison (1994) observed a dramatic shift in mean home range size from 1,280 ha (breeding season) to 3,180 ha (nonbreeding season) for five females.

Food availability may affect home range size. High levels of food availability in the Upper Great Lakes associated with grouse and snowshoe hare cycles may lead to smaller home range sizes for the goshawk. Often at the extreme northern latitudes, food is less abundant, forcing goshawk to travel greater distances to find prey (Iverson *et al.*, 1996). Iverson *et al.* (1996) calculated median home range size of 3,906 ha for females during the breeding season in Alaska. The largest size of home range (maximum=86,766 ha) was speculated to result from usage of aircraft for obtaining radio telemetry locations, since aerial telemetry can detect transmitter signals from extreme distances.

Radio telemetry data often can be biased. Populations may not be accurately represented by individual birds chosen in these types of studies. Study animals may be forced into less suitable habitat due to competition limitations. Competition for territories or resources by conspecifics or other raptor species can influence habitat use. For instance, if a red-tailed hawk is defending its territory, regardless of size, this represents an area that goshawks will likely not utilize.

In general, most goshawks in my study selected hardwood/conifer mix and swamp fir/swamp conifer cover types, and many appear to have avoided cover types containing only one tree species or one identifiable component (i.e., aspen, cedar, jack pine). Goshawks in my study appeared to choose habitat types consistent with their primary prey species, ruffed grouse and snowshoe hare. Both prey species were abundant in prey remains below all nest trees monitored. Grouse, can be found throughout the year in various forest types with an aspen component (Urbain, 1991). Snowshoe hare in Michigan thrive in coniferous, low-lying cedar bogs and spruce swamps (Kurta, 1995). My sample of goshawk appeared to select home ranges that included many swamp fir/swamp conifer habitats in both breeding and nonbreeding seasons. Similarly, telemetry points occurred at a higher than expected frequency in this habitat, as well as hardwood and hardwood/conifer mix during the nonbreeding season. Vegetative diversity may be a necessary component of the habitat structure used by foraging goshawks. A diversity of forest types may provide many species of prey for the goshawks in the UP-MI.

Goshawks in my study selected and avoided a variety of habitats with no clear consistency, with the exception of the hardwood, hardwood/conifer mix and swamp fir/swamp conifer cover types. In addition to snowshoe hare and grouse remains, we also found the remains of red squirrel (*Tamaisciurus hudsonicus*), woodcock (*Scolopex minor*), blue jay (*Cyanocitta cristata*), many species of woodpeckers (*Picoides* spp.), northern flicker (*Colaptes auratus*) and even a wood duck (*Aix sponsa*). Red squirrel, blue jay, northern flicker and many species of woodpecker are habitat generalists and can be found in a wide variety of habitat types. Selection of various species of prey may further illustrate that goshawks choose a variety of habitats with high species diversity. From this study, it is apparent that goshawks chose no one particular habitat and may actually require a variety of habitats for hunting. Newton (1979) concluded that forest areas of varied structure and tree composition generally support more wildlife than do the managed, monotypic, stands. Hargis *et al.* (1994) concluded that goshawk home ranges in eastern California tended to be located in areas with high vegetative and seral diversity. They attribute the proximity of telemetry locations to high vegetative diversity, to the availability of prey. Kenward and Widen (1989) found that goshawk home ranges during the nonbreeding season in central Sweden varied with productivity of the prey in the associated habitat. Home ranges were smallest (20 square km) in areas where pheasants were released.

My study of goshawks in the UP-MI should be viewed as a preliminary project to provide the framework for further research. From this study, standard operating procedures have been established on capture, banding, transmitter attachment, and radio-telemetry procedures for goshawks. The protocol has been developed on how to collect, enter and analyze radio-telemetry data. These resources should be utilized for future study of the home range and habitat use of not only the goshawk, but also other raptors significant to the understanding of goshawk ecology in the UP-MI as well as the entire Upper Great Lakes region.

CHAPTER 3

SUMMARY AND RECOMMENDATIONS

This study provides a framework for future investigation of the ecology of the goshawks in the UP-MI, LP-MI, NE-WI, and NW-WI. It appears that the best method for locating breeding pairs of goshawks is reports and maintaining a database of historic territories. Interacting with resource professionals and resource agencies is essential to this strategy.

Productivity of the goshawk in the UP-MI and other Upper Great Lakes regions appears to be within the range of values for the western states. Most important to the understanding of a sustainable productivity level for the goshawk is long-term monitoring. Banding data should be utilized to determine age-specific survival to further understand goshawk productivity and to develop population models.

The home range and habitat use component of this study was developed to determine the cover types goshawk used at random times throughout the breeding and nonbreeding seasons. Although only a small number of goshawks were observed, this was accomplished, and several conclusions can be drawn. Goshawks in the UP-MI have smaller breeding season home ranges than goshawks in the western states, and adult nonbreeding season home ranges expand considerably as young leave the nest area. Goshawks also appear to be choosing habitats with very high tree species composition and avoiding monotypic stands. They appear to select a mixed-forested condition consisting of habitats with a conifer component as well as a hardwood component. The availability of prey is likely to be an important factor in their choice of habitat. Forest age structure was not investigated in this study, but is an important component of habitat use that should be studied, especially in terms of land use management practices affecting critical goshawk habitat. What we do not know at this point are the effects on reproductive success of habitat alteration and the occurrence of the fisher and other predators.

Predator activity should be monitored aggressively in all research areas. Mammal track surveys could be done in winter to estimate predator abundance. The occurrence of fisher in nearly all territories, excluding the LP-MI, is an important factor to consider in productivity monitoring. Fisher might be having a greater impact on reproduction than initially expected.

In terms of habitat use, much more research is required before recommendations can be developed in the UP-MI. However, for measuring productivity in the future, maintaining goshawk nesting territories should be a vital concern for land managers in the UP-MI. In doing so, land managers can gain an understanding of occupancy and reoccupancy of nest sites from one year to the next as well as identifying productivity trends and factors affecting productivity. The Hiawatha National Forest has implemented a set of nest site guidelines designed by the Huron-Manistee National Forests in LP-MI for conservation of the goshawk (Ennis *et al.*, 1993). These guidelines recognize the nest area as 12 ha immediately around the nest tree and the post-fledgling area was defined as approximately one half-mile radius from the nest. This area is generally centered on the active nest area and usually includes alternate nest sites within the territory. The guidelines recommend fully protecting the 12 ha nest area from any adverse management activities. If any land management must occur just outside of this area, it will be outside of the breeding season (1 March-31 August). Management in the post-fledging area would consist of maintaining a mosaic of vegetative structural stages. These stand conditions should provide areas which have canopy coverage greater than 50%, some areas with well-developed understories, snags and down woody debris for maintenance of the prey base (Ennis *et al.* 1993). These guidelines should be uniform and consistent throughout Wisconsin and Michigan and should be implemented and tested to compare productivity with control sites over an extended period of time. I think this is essential to aid land managers in their ability to determine if these guidelines are actually meeting the requirements of the goshawk in the Upper Peninsula.

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Appendix A. Reproductive outcomes for 36 breeding areas of northern goshawks in the Upper Peninsula of Michigan during 1996-1999.

Year	Location	Fledged Young	Young Banded	Comments
1996*	HNF	1	0	Observed 1 fledgling at nest, 7/2/96
1996*	HNF	0	0	No young observed
1996*	HNF	0	2	2 young dead; mammalian predation
1996*	HNF	0	0	No young observed
1996*	HNF	1	0	1 fledgling observed off nest, 7/25/96
1996*	HNF	0	0	No young observed
1996*	HNF	0	0	No young observed
TOTAL		2	2	
1997*	LSSF	2	0	
1997*	LSSF	1	0	
1997*	Private	3	0	
1997*	HNF	3	0	New nest within territory
1997*	HNF	2	0	Probably last year's 3 Lakes
1997*	HNF (East Unit)	2	0	
TOTAL		13	0	
1998	ONF	1	0	At least 1 young fledged
1998	ONf	0	0	Young gone prior to fledging; no cause
1998	ONF	2	1	1 fledgling dead; mammalian predation
1998	CIC/MC	1	2	1 fledgling dead: mammalian predation
1998	CIC/MC	0	2	Both young dead; mammalian predation
1998	HNF	2	2	Both fledged
1998	HNF	0	0	1 young dead; fisher predation
1998	HNF	0	0	1 young dead; mammalian predation
1998	HNF	0	0	Nestlings dead; mammalian predation
1998	HNF	1	1	Lone nestling fledged
1998	HNF (East Unit)	2	2	Both fledged
TOTAL		9	10	
1999	HNF (East Unit)	2	3	1 lost to unknown causes
1999	LSSF	2	2	Both fledged
1999	LSSF	2	2	Both fledged
1999	LSSF	3	0	Fledglings on adjacent tree, 7/1/99
1999	HNF	1	2	Only one fledgling observed, 7/2/99
1999	HNF	2	0	2 fledglings on adjacent trees, 7/2/99
1999	HNF	1	2	1 fledgling dead; mammalian predation
1999	CIC/MC	0	0	Young gone prior to fledging; no cause
1999	ONF	2	0	Fledglings observed on adjacent trees
1999	Private	1	0	1 young on adjacent, 6/30/99
1999	SNWR	1	0	1 young fledged
1999	HNF	0	0	Adult found dead below nest tree
TOTAL		17	11	
Young Fledged		**41**		**HNF=Hiawatha National Forest**
Predation Loss		**10**		**LSSF=Lake Superior State Forest**
Unknown Results		**6**		**ONF=Ottawa National Forest**
				CIC=Champion Inter. Corporation
Productivity 1996-99 (Young fledged/occ. Nest)		**1.14**		**MC=Mead Corporation**
				SNWR=Seney Nat. Wildlife Refuge
				***Data from Christianson, 1998**